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TENSILE STRENGTH AND ELASTICITY OF WOOL

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INTRODUCTION

The study of the tensile strength and elasticity of wool is comparatively a new line of investigation. McMurtrie,[1] of Illinois, in cooperation with the United States Department of Agriculture, tested a great number of fibers, and Prof. J. A. Hill, of the Wyoming Agricultural Experiment Station, Laramie, Wyo., did considerable work along this line. Other than that, so far as the writer knows, there has been no research on this problem in the United States.

The exact structure of wool is not well understood. It differs from a hair in that the medullary, or central, layer of cells, corresponding to the heart of a tree, is absent in true wool. The coarse wools, however, possess this layer to some extent and, hence, might be termed "hair" in one sense of the word. The line of distinction can not be sharply drawn.

McMurtrie [1] measured the breaking strain and elasticity of over 35,000 fibers, representing nearly 1,000 samples. He tested 30 fibers per sample to secure a fair average test. In another series tested a few years later a small lock was taken from each sample and the fibers were drawn at random. In this way it was found necessary to test 50 fibers of each sample to obtain a true average.[2]

Matthews [3] makes the following statement in regard to this point:

> A fair average of breaking strain and elasticity may be obtained for any quality of fibre by testing about 10 separate fibres and taking the mean of the total tests. If the quality of fibres, however, in a sample does not run very uniform it is best to increase the number of tests to 25 or even 50 in order that a satisfactory average may be obtained.

Prof. Hill and assistants tested in all 59,400 fibers and proved the fallacy of using only 10 to 50 fibers for a true average. He tested 1,000 fibers per sample and divided them into groups of 100. Four of the means of the groups of 100 differed from the mean of the 1,000 by more

[1] McMurtrie, William. Report upon an Examination of Wools and Other Animal Fibers ... made under the direction of the Commissioner of Agriculture. p. 217. Washington, D. C., 1886. Pub. by the U. S. Dept. Agr.

[2] Id., p. 425.

[3] Matthews, J. M. The Textile Fibres ... ed. 1, p. 274. New York, 1904.

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than 4 per cent, and between the mean of the sixth and the mean of the seventh hundred there was a difference of 14.63 per cent. He says:[1]

A result such as this from the first experiment shows that, even if this were an exceptional case, it is at least necessary to test several more samples before deciding to base any conclusions upon means of so few as 100 measurements.

At the Wyoming Experiment Station as high as 10,000 fibers from one sheep were tested for breaking strain and divided into groups of 5,000 each, on which Hill comments as follows:[2]

Notwithstanding the fact that for most purposes the drawing and testing of 5,000 fibers of wool in order to determine the tensile strength of a sample would be highly impracticable, Table III shows that where the samples were not carefully mixed before drawing the sub-samples, the means of this number in two samples differ by more than 5% when only two and three means are compared.

NECESSITY FOR A METHOD OF TESTING WOOL

On July 1, 1908, a project in wool research was undertaken by Prof. R. W. Clark, of the Montana Experiment Station. The object was to study the effect of various factors—feeding, breeding, care, management, etc.—upon the wool and form of the sheep.

The first step necessary was to work out a method to test accurately the qualities of the wool fibers. This has proved a long and tedious task, owing to the excessive variation among the fibers.

In the sample of Rambouillet wool, fibers grown side by side varied in breaking stress from 20 to 140 dgm. Also the stretch or strain varied from 1 to 15 mm. Hence, it is self-evident that a great many fibers would have to be tested to reduce this variation to a minimum.

Table I gives the results obtained by testing 1,000 fibers from the same place on the body of the sheep for breaking stress. Five samples were taken from each sheep.

TABLE I.—*Results of testing fibers of wool for breaking stress*

Sheep No.	Shoulder.	Back.	Side.	Belly.	Hip.
	Dgm.	*Dgm.*	*Dgm.*	*Dgm.*	*Dgm.*
324	55.994±0.404	53.127±0.407	56.566±0.502	58.13 ±0.437	54.652±0.496
6283	56.146±0.452	53.894±0.502	50.523±0.440	51.868±0.298	62.702±0.575
6382	55.717±0.325	57.56 ±0.431	63.502±0.417	46.97 ±0.298	65.696±0.576

To explain the notation, let us consider for an illustration the shoulder of sheep No. 324, which is given as 55.994±0.404. By this is meant that the average breaking stress of the 1,000 fibers was 55.994 dgm., and the probable variation for the 1,000 was 0.404 dgm.—i. e., the chance is even that if another lot of 1,000 fibers were taken from the same place, the

[1] Hill, J. A. Studies on strength and elasticity of the wool fiber. 1. The probable error of the mean. Wyo. Agr. Exp. Sta. 21st Ann. Rept., 1910/11, Sup., p. 16. 1911.

[2] Hill, J. A. The value of fiber-testing machines for measuring the strength and elasticity of wool. Wyo. Agr. Exp. Sta. Bul. 92, p. 22. 1912.

average breaking stress would lie between 55.994 − 0.404 = 55.590 dgm. and 55.994 + 0.404 = 56.398 dgm. In this case the probable variation of a single fiber would be 12.764—i. e., we should expect that one-half of the fibers would have a breaking stress lying somewhere between 43.230 and 68.758 dgm.

At the same time that these observations were taken, a record was kept of the ultimate strain of each fiber. But no account was taken of the length of each fiber at the time stress was imposed. However, it was evident that the ultimate strain was very slightly, if at all, a function of the breaking stress.

BREAKING STRESS AND TENSILE STRENGTH[1]

The first work on this project was the determining of the breaking stress of the fibers and the probable variation in the same, for the purpose of getting an average with a probable variation so small that it could be disregarded. It was found, however, that the variation was too great to give conclusive results even when using as high as 5,000 fibers per fleece. This was to be expected in part, as to compare wool fibers without regard to their sizes does not seem to be practicable.

It was decided, therefore, that the ultimate breaking stress of the fibers was not what was wanted, but rather the quality of the fabric woven from the wool. The strength of the fabric depends upon the tensile strength of the fibers—i. e., the breaking stress divided by the cross section of the fiber.

Each fiber of coarse wool has a greater breaking stress than single fibers of fine wool, yet a piece of goods made from the fine wool will contain many more fibers to the yard than one made from the coarse wool; thus, the former may make the stronger cloth. It is therefore evident that we must know the cross section of each fiber as well as the breaking stress. The results from testing the fibers on this basis is illustrated by the following samples of wool: Rambouillet No. 6401—breaking stress, 49.35 dgm.; tensile strength, 100.988. Shropshire No. 67—breaking stress, 140.00 dgm.; tensile strength, 119.886. It will be seen that while the ratio of the breaking stress is 1 to 2.83, that of the tensile strength

[1] EXPLANATION OF TERMS USED:

Length (L)—length of fiber tested, in millimeters.

Diameter (D)=measured on the microscope with a micrometer eyepiece. 1 unit equal 1.5μ.

Area (A)=area of cross section of fiber. Formula $\frac{\pi D^2}{4}$.

Breaking stress (S)=force required to break fiber, in decigrams.

Strain (E)=stretch or elongation of fiber, in millimeters.

Tensile strength (TS)=strength per unit area $\frac{S}{A}$. However, to save time in our calculation we computed a value $\frac{S}{D^2}$ which is the constant $\frac{4}{\pi}\times TS$.

Elastic limit (EL)= point at which if more force is applied, Hook's law $\frac{S}{E}=K$ breaks down.

Young's modulus (Y)=a formula used for measuring material which is based on Hook's law. $\frac{\text{Stress}}{\text{Strain}}$=a constant. Formula, $\frac{L\times S}{E\times A}$.

Probable variation (PV)=a value which in the long run is greater than the variation of exactly one-half the fibers from the mean.

is only 1 to 1.19. Thus, in comparing the breaking stresses we get a greatly distorted idea of the difference in the strength of the fabric that would be manufactured from the wool.

A large number of tests were then made to determine the tensile strength of the fibers. The results are given in Table II.

TABLE II.—*Results of testing fibers of wool for tensile strength—sheep 6398; sample from hip*

Lot of fibers.	Stress.	Coefficient of variation.	Tensile strength.	Coefficient of variation.
	Dgm.	*Per cent.*	*Dgm.*	*Per cent.*
First 100	46.28±1.53	3.31	74,765±2,146	2.65
Second 100	44.75±1.26	2.82	75,293±1,573	2.09
Third 100	51.73±1.19	2.30	76,973±1,452	1.88

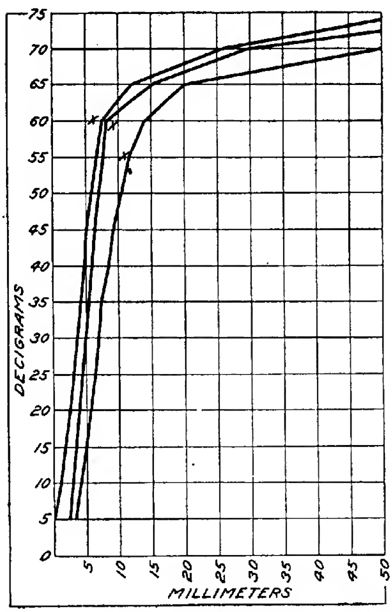


FIG. 1.—Curve showing the regularity of stretch and the abrupt break of merino wool after the elastic limit is passed. X = elastic limit.

This shows an average coefficient of variation of 2.81 per cent for the stress and 2.21 per cent for the tensile strength.

ELASTIC LIMIT

However, there are other elements that are even more important than the tensile strength. We do not care so much that a fabric shall have a high resistance to a tearing force as that it shall have wearing qualities. If we catch our clothes on a nail and tear them, the force exerted is usually so great that any slight variation in the strength of the cloth will make no difference. Young's modulus, which is the stress per unit area of cross section divided by the strain per unit length, will show the degree with which a fabric will withstand deformation under ordinary forces. Thus, we expect to find that when the wool has a high

Young's modulus a fabric manufactured from it will have high resistance to deformation of shape.

By what is known as Hook's law, the stress divided by the strain is constant to a certain point and from that time on the ratio decreases. This point is known as the elastic limit of the substance, and in determining Young's modulus we always take the observations before the elastic limit is reached. When a force is applied that carries the deformation beyond the elastic limit, the wool will not come back to its original shape. In fact, this force has begun to tear apart the molecules of the fiber, and the wool has become permanently weakened. Thus, a record of the elastic limit for the fibers is essential.

FIG. 2.—Curve showing Young's modulus of elasticity of merino wool at different stresses. X=elastic limit.

Figures 1 and 2 show the curves illustrating the elastic limit. The former shows the stretch or strain as force is applied; the latter shows the modulus curve.

Table III gives the variation in the elastic limits for various fibers, as obtained from three sheep.

TABLE III.—*Variation in the elastic limits of wool fibers of three sheep*

Sheep No.	Column 2.	Column 3.
	Dgm.	*Dgm.*
81	42.90±0.7608	17.54±0.2320
82	34.95± .8768	17.54± .2934
676	79.90±1.7476	17.46± .2901

In column 2 is given the average tension per wool fiber at the time of passing the elastic limit. In column 3 is given the average tension at the time of passing the elastic limit on an area of the wool fiber equivalent to the area of cross section of a wool fiber whose diameter is 15μ. The first two of these sheep were range-bred merinos and the third was a pure-bred Shropshire. The Shropshire has much coarser wool fibers; consequently the large value in column 2. But, in spite of the difference in breed and a large variation in the size of wool fibers between Shropshires and merinos when reduced to the tension on equal areas of cross section, we find great uniformity for the three sheep. These three sheep had received similar care and feed. We should expect a greater variation in elastic limit than shown above for sheep of the same breed under different conditions as to feed, shelter, etc.

DESCRIPTION OF TESTING APPARATUS

The apparatus used in these tests consists of (1) a fiber-testing machine devised for the Philadelphia Textile School and (2) a compound microscope with micrometer eyepiece attached for accurate measuring of the diameter of the fibers.

The following description of the fiber-testing machine is given by Matthews[1] (Pl. LVII, fig. 1 and 2).

> The fibre to be tested is clamped between the jaws at (J), the pointer attached to the end of the beam above the upper jaw being brought to the zero-mark on the scale (S), while the lower jaw is raised or lowered in its stand until the desired distance between the jaws is obtained. To obtain comparable results this distance should always be the same. [We have used 40 mm. for our observations.] The sliding-bar (R) is moved forward by turning the rod (T), which moves the rack and pinion at (P), until the graduation on the wheel (G) is at zero to the indicator. Under these conditions there is no strain on the fibre. A stretching force is then placed on the fibre by moving the bar (R) backward by turning the rod (T); the motion of this bar is made uniform and gradual until the fibre finally breaks under the strain thus placed upon it. The graduation on the wheel (G) will then indicate in decigrams the breaking strain of the fibre being tested. The elasticity is obtained by watching carefully the pointer moving up the scale of millimeters at (S) until the rupture of the fibre takes place; the distance this pointer moves represents the actual stretch of the fibre. . . . The weight (W) at the rear end of the beam can be moved backward or forward, and is for the purpose of adjusting the balance so that there is no strain at (J) when the indicator (G) marks zero. The wheel (G) is graduated in decigrams, and this marks the sensibility of the machine; the total graduations on (G) running from zero to 400. When fibres are tested having a greater tensile strength than 400 decigrams a fixed additional weight of 10, 25, 50, etc., grams may be hung from (W), and this must be added to the reading on the wheel when the fibre breaks. If the elasticity of the fibre is so great as to carry the pointer beyond the limits of the scale at (S), a shorter length of fibre must be tested.

[1] Matthews, J. M. Op. cit., p. 272–274, fig. 69.

IMPROVED TESTING APPARATUS

Because of the difficulty of making accurate readings on the scale of the fiber-testing machine, the following apparatus was devised to be used with it:

(1) An illuminated scale with the lamps inclosed to prevent reflection; (2) an optical lever attached to the testing machine; (3) a large plain mirror; and (4) a high-power telescope.

The instruments are so arranged that the illuminated scale, A, is thrown onto the optical lever, B, by means of which it is reflected onto the mirror, C, from which it is read through the telescope, D (Pl. LVII, fig. 3).

The telescope magnifies about 28 times, and the distance between the scale and the optical lever is such that the total magnification is just 50. In this way very accurate readings can be taken.

To test a fiber, the machine is first balanced so that it is in perfect adjustment with the optical lever attached. A fiber is then put between the jaws of the machine and 10 dgm. of force applied to take out the crimp or waviness, making the fiber perfectly tight. A reading is taken at this point and again when 15 dgm. of force is applied and again at every 5 dgm. additional until the fiber passes the elastic limit. After the elastic limit is passed, force is gradually applied until the fiber breaks. A portion of it is mounted on a slide and the diameter obtained under the microscope by means of a micrometer eyepiece. Young's modulus and tensile strength can then be determined.

EXPLANATION OF DIAGRAMS

Mention has been made of the great variation in the fibers taken from the same place upon the sheep's body. By means of figure 3 we can express these variations more definitely. If, for example, we are investigating the tensile strength of fibers, the best value to take would be the average of that found for the separate fibers. But, if observations had been taken on a hundred fibers, we should not expect that average to be the same as for another hundred taken from the same place. It is therefore necessary not only to take the average but the probable variation—i. e., an amount such that, if added to and subtracted from, the average obtained will give two numbers such that the average for another hundred would have even chances of lying between these two numbers. If two samples of wool from different places on a sheep, from different sheep, or from the same place under different treatment have been examined and the tensile strength with probable variation determined, we must have a means of knowing with what certainty we may state that one is stronger than the other and by how much. While the fibers which have the highest average will have a probability of being the strongest, that probability may be very slight and, in fact, so slight that we hardly dare make any

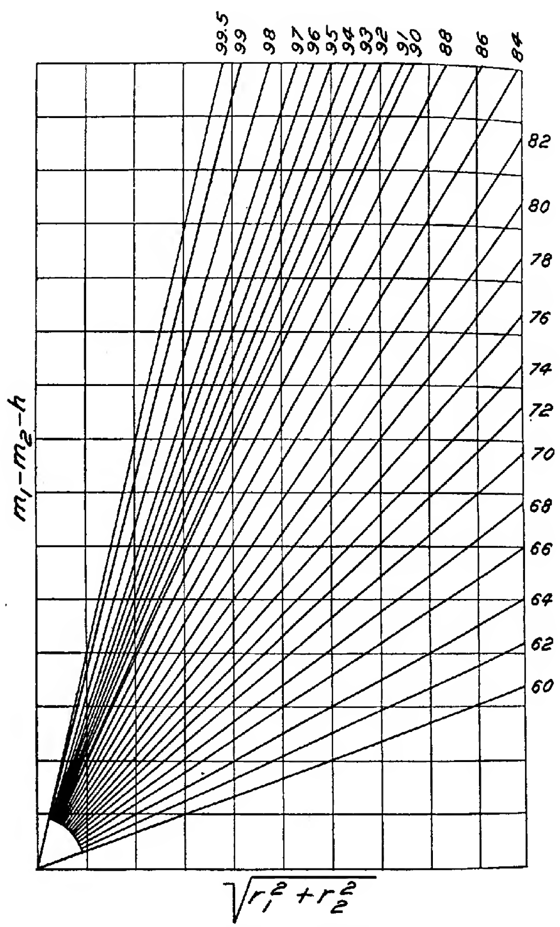


FIG. 3.—Diagram for plotting curves by means of which the percentage of accuracy of the tensile strength of wool when comparing two sets of observations may be exactly calculated.

statement as to their relative strength. To give definite information as to their relative strength, when the averages and probable variations are given, figure 3 has been devised, from which may be read the percentage probability that one lot of fibers is stronger than the other; also, the percentage probability that it is stronger by any given amount.

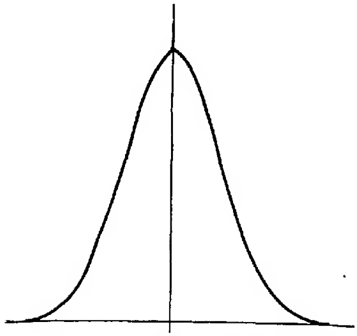


FIG. 4.—Curve of ordinary probability. The abscissæ are taken as a variation in strength of a given fiber from the mean strength of all the fibers and the ordinates are proportional to the probability that such a fiber exists.

Suppose two sets of observations give $m_1 \pm r_1$ and $m_2 \pm r_2$ and we wish to show the probability that the first is greater than the second by an amount h. Knowing the probable variation, r, a curve can be drawn whose highest ordinate is to the ordinate of any point whose abscissa is x as the number of fibers whose strength is the average is to the number of fibers whose strength is x more than the average. In this case, we take x to be either a positive or a negative number.

The equation of this curve is $y=\frac{.4769}{r_1\sqrt{\pi}}e^{-\left[\frac{.4769x}{r_1}\right]^2}$. Figure 4 is an illustration of this curve.

The probability that the actual strength of fibers recorded as m_2+r_2 is within dx of m_2+x is $\frac{.4769}{r_2\sqrt{\pi}}e^{-\left[\frac{.4769x}{r_2}\right]^2}$.

The probability that the strength of fibers given as $m_1 \pm r_1$ is m_2+x+h or just h greater than the other is

$$\frac{.4769}{r_1\sqrt{\pi}}e^{-\left[\frac{.4769(m_2-m_1+x+h)}{r_1}\right]^2}dh.$$

Hence, the probability that the fibers given as m_2+r_2 have a real strength m_2+x and the other just h greater is

$$\frac{(.4769)^2}{r_1r_2\pi}e^{-\left[\frac{.4769x}{r_2}\right]^2}e^{-\left[\frac{.4769(m_2-m_1+x+h)}{r_1}\right]^2}dx.dh.$$

And the probability that the former has a strength m_2+x and the latter a strength at least h greater is

$$\frac{(.4769)^2}{r_1r_2\pi}dx\int_h^\infty e^{-\left[\frac{.4769x}{r_2}\right]^2}e^{-\left[\frac{.4769(m_2-m_1+x+h)}{r_1}\right]^2}dh.$$

Now, if we let x take all possible values, we have as the probability that the group recorded with the strength m_1+r_1 is at least stronger than the other the double integral

$$\frac{(.4769)^2}{r_1 r_2 \pi}\int_{-\infty}^{\infty}\int_{k}^{\infty} e^{-\left[\frac{.4769x}{r_2}\right]^2} e^{-\left[\frac{.4769(m_2-m_1+x+h)}{r_1}\right]^2} dx.dh.$$

Designating this probability by p and letting $\frac{.4769}{r_1}(m_2-m_1+x+h)=t$, we shall have the equation

$$p=\frac{.4769}{r_2\pi}\int_{-\infty}^{\infty}\int_{\frac{.4769}{r_1}(m_2-m_1+x+h)}^{\infty} e^{-\left[\frac{.4769x}{r_2}\right]^2} e^{-t^2} dx.dt.$$

By breaking this integral into two, we may write our equation as follows:

$$p=\frac{.4769}{r_2\pi}\int_{-\infty}^{\infty}\int_{0}^{\infty} e^{-\left[\frac{.4769x}{r_2}\right]^2} e^{-t^2} dx.dt.$$

$$-\frac{.4769}{r_2\pi}\int_{-\infty}^{\infty}\int_{0}^{+\frac{.4769}{r_1}(m_2-m_1+x+h)} e^{-\left[\frac{.4769x}{r_2}\right]^2} e^{-t^2} dx.dt.$$

The first of these integrals can be evaluated by a well-known method in definite integrals. Its value is ½. The second integral we shall call q. Then placing $m_2-m_1+h=k$, we obtain the following:

$$q=\frac{.4769}{r_2\pi}\int_{-\infty}^{\infty}\int_{0}^{+\frac{.4769}{r_1}(k+x)} e^{-\left[\frac{.4769x}{r_2}\right]^2} e^{-t^2} dx.dt$$

$$\frac{dq}{dk}=\frac{(.4769)^2}{r_1 r_2\pi}\int_{-\infty}^{\infty} e^{-(.4769)^2\left[\left(\frac{x}{r_2}\right)^2+\left(\frac{k+x}{r_1}\right)^2\right]}dx.$$

or

$$\frac{dq}{dk}=\frac{(.4769)^2}{r_1 r_2\pi} e^{-\frac{(.4769k)^2}{r_1^2+r_2^2}}\int_{-\infty}^{\infty} e^{-\left[.4769\left(\frac{x\sqrt{r_1^2+r_2^2}}{r_1 r_2}+\frac{kr_2}{r_1\sqrt{r_1^2+r_2^2}}\right)\right]^2}dx.$$

Now, by putting $.4769\left(\frac{x\sqrt{r_1^2+r_2^2}}{r_1 r_2}+\frac{kr_2}{r_1\sqrt{r_1^2+r_2^2}}\right)=u$ we shall have

$$\frac{dq}{dk}=\frac{.4769}{\pi\sqrt{r_1^2+r_2^2}}\int_{-\infty}^{\infty} e^{-\frac{(.4769k)^2}{(r_1^2+r_2^2)}} e^{-u^2}du.$$

Integrating with respect to u, we have $\frac{dq}{dk}=\frac{.4769}{\sqrt{\pi}\sqrt{r_1^2+r_2^2}}e^{-\frac{(.4769k)^2}{r_1^2+r_2^2}}$. Substituting $\frac{.4769k}{\sqrt{r_1^2+r_2^2}}=s$ and putting the equation into the integral form, we shall have $q=\frac{1}{\pi}\int_0^{\frac{.4769k}{\sqrt{r_1^2+r_2^2}}}e^{-u^2}du$. Now, tables are made for the integral $\int_0^t e^{-t^2}dt$ when t is a constant. Now, $k=m_2-m_1+h$; r_1 and r_2 are known, so q can be taken from this table. Returning to p, we have $p=\frac{1}{2}-q$. The value of q evidently depends upon the ratio of $-k$ to $\sqrt{r_1^2+r_2^2}$. Taking these two values as the ordinate and the abscissa of a point, it is evident that all points on a straight line passing through the origin of coordinates would give the same value p. Given p, we may determine the slope of the line corresponding to the given value of p. On a sheet of cross-section paper (fig. 3) lines have been drawn corresponding to certain values of p.

As an example of the use of this diagram, observations on two sets of wool gave as their tensile strengths the following results: (a) $101{,}180\pm 2{,}219$ and (b) $75{,}293\pm 1{,}573$ dgm. per sq. mm. $m_1-m_2=25{,}887$ $\sqrt{r_1^2+r_2^2}=(2{,}219)^2+(1{,}573)^2=2{,}719.05$. Taking each of the smallest divisions as 200, we see that the chances are more than 9,999 out of 10,000 that the fibers in group a are the stronger. Now, taking h successively as 5,000, 10,000, 15,000, 20,000, and 25,000, we shall have the quantity m_1-m_2-h taking successively the values 20,887, 15,887, 10,887, 5,887, and 887. Taking each of the smallest divisions as 100, we see that the chances are more than 9,999 out of 10,000 that group a is at least 10,000 dgm. per sq. mm. stronger than b. The chances are practically 995 out of 1,000 that group a is at least 15,000 dgm. per sq. mm. stronger than b. The chances are 92 out of 100 that group a is at least 20,000 dgm. per sq. mm. stronger than b and 6 out of 10 that it is at least 25,000 dgm. per sq. mm. stronger than b. Reading these facts in another way, we may state with the probability of being correct 60 per cent of the time that the fibers of group a are at least 25,000 dgm. per sq. mm. stronger than those of group b; 70 per cent of the time that group a is at least 23,700 dgm. per sq. mm. stronger than group b; 75 per cent of the time that group a is at least 23,150 dgm. per sq. mm. stronger than group b; 80 per cent of the time that group a is at least 22,500 dgm. per sq. mm. stronger than group b; 85 per cent of the time that group a is at least 21,750 dgm. per sq. mm. stronger than group b; 90 per cent of the time that group a is at least 20,700 dgm. per sq. mm. stronger than

group b; 95 per cent of the time that group a is at least 19,250 dgm. per sq. mm. stronger than group b; 99 per cent of the time that group a is at least 15,700 dgm. per sq. mm. stronger than group b; 99.9 per cent of the time that group a is at least 13,500 dgm. per sq. mm. stronger than group b and 99.99 per cent of the time that group a is at least 11,000 dgm. per sq. mm. stronger than group b. We thus read immediately the degree of accuracy to which any measurement is entitled.

As a further illustration, a series of tests were taken on the breaking stresses, diameters, tensile strengths, Young's moduli, and elastic limits of the fibers of samples of wool clipped from the same sheep in successive years, to determine the effect of the age of the sheep on the wool. Taking two of these elements—namely, the breaking stress and elastic limit—it may be shown how accurately we may state the probable tendency of change from year to year (Table IV).

TABLE IV.—*Probable change in the breaking stress and the elastic limit of fibers of wool*

Clip.	Observed.		Probability of decrease in breaking stress.	Observed.		Probability of decrease in elastic limit.
	Breaking stress.	$\sqrt{r_1^2+r_2^2}$		Elastic limit.	$\sqrt{r_1^2+r_2^2}$	
	Dgm.			*Dgm.*		
1908...	64.22±1.428			18.44±0.2347		
		1.95	0.68		0.36	[a] 0.87
1909...	62.91±1.325			18.81± .2832		
		1.74	.79		.37	.9998
1910...	60.81±1.1286			18.64± .2698		
		1.53	.9999		.43	.52
1911...	52.03±1.0792			16.61± .3263		
		1.7	[a] .9999		.43	[a] .69
1912...	68.12±1.3871			16.91± .2556		
		1.84	.9999		.38	.9999
1913...	52.26±1.248			13.39± .2954		

[a] Increase.

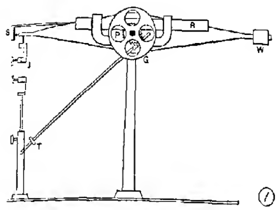
Table shows that in case of the breaking stress the chances are approximately 2 to 1 and 3 to 1 that there was a decrease in the breaking stress from the first to the second and from the second to the third year, respectively, and does not permit us to make a decided statement that there was a decrease those two years. On the other hand, the chances are better than 10,000 to 1 that from the third to the fourth year and from the fifth to the sixth year there was a decrease as well as from the fourth to the fifth there was an increase in breaking stress. Likewise, we are practically certain that there was a decrease in tensile strength from the second to the third and from the fifth to the sixth years, while in the case of other years the probability is not great enough to justify any very decided statement.

PLATE LVII

Fig. 1.—Diagrammatic drawing of the fiber-testing machine of the Philadelphia Textile School. "*J*, Jaws with screw clamps for holding the fiber; the lower jaw may be raised or lowered; *R*, sliding rod working on a rack and pinion; this takes the place of weights; *G*, wheel graduated on its face in decigrams, moving on the same axis as the pinion for sliding the weight; *T*, thumbscrew for turning the small shaft working the pinion at *P*; *W*, counterbalancing weight for regulating the zero point of the machine; *S*, scale for reading the sketch of the fiber." (From Matthews' The Textile Fibres.)

Fig. 2.—Fiber-testing machine removed from its case.

Fig. 3.—Diagram showing the arrangement of the wool-testing apparatus at the Montana Agricultural Experiment Station.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R
P
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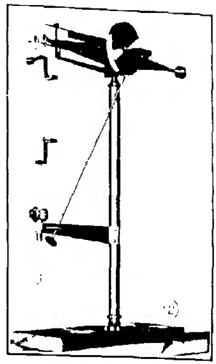

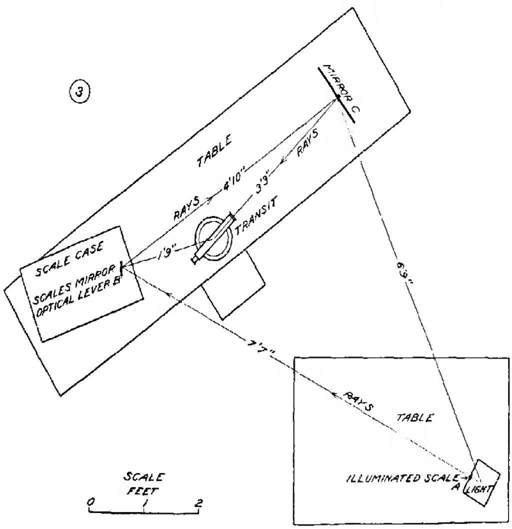
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INFLUENCE OF HYBRIDIZATION AND CROSS-POLLINATION ON THE WATER REQUIREMENT OF PLANTS

By LYMAN J. BRIGGS, *Biophysicist in Charge, Biophysical Investigations*, and H. L. SHANTZ, *Plant Physiologist, Alkali and Drought Resistant Plant Investigations, Bureau of Plant Industry*

INTRODUCTION

In breeding plants for drought resistance it is desirable to know whether the water requirement of the hybrid progeny bears a definite relationship to the water requirement of its parents. That hybridization may result in increased drought resistance is indicated by the work of Collins,[1] who observed that certain first-generation hybrids of maize suffered less from drought than the parents grown under the same conditions. The behavior of these hybrids suggests that they may be exceptionally efficient in the use of water, a point of practical importance in connection with drought resistance. This consideration, combined with the fact that water-requirement measurements constitute a physiological expression of the effects of hybridization, led the writers to measure the water requirement of a number of hybrids and their parents, the subject being one which has not heretofore been quantitatively investigated. These measurements, which were conducted at Akron, Colo., were made possible through the courtesy of Mr. G. N. Collins, of the Office of Crop Acclimatization and Adaptation Investigations, Bureau of Plant Industry, who supplied seed of a number of first-generation hybrids of maize and their parent strains. Mr. J. H. Parker, of the Office of Cereal Investigations, Bureau of Plant Industry, also kindly furnished seed of a hybrid strain of wheat and its parent strains.

The term "water requirement" is here used to designate the ratio of the total weight of water absorbed by the plant during its growth to the total dry matter produced, excluding the roots. The plants were grown in large iron pots of a type already described.[2] To exclude rainfall and prevent evaporation from the soil as far as possible, each pot was provided with a tight-fitting cover having openings for the plants, the annular space between the stalk and the cover being closed with a plastic wax. The plants made a normal growth, as reference to Plate LVIII will show.

[1] Collins, G. N. The value of first-generation hybrids in corn. U. S. Dept. Agr. Bur. Plant Indus. Bul. 191, p. 32. 1910.

[2] Briggs, L. J., and Shantz, H. L. The water requirement of plants. I.—Investigations in the Great Plains in 1910 and 1911. U. S. Dept. Agr. Bur. Plant Indus. Bul. 284, p. 9. 1913.

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MAIZE HYBRIDS

In order to make a satisfactory comparison of the water requirement of a hybrid with that of its parents, it is necessary to have the plants growing under as nearly identical conditions as possible. Each determination includes, therefore, the measurement not only of the water requirement of the hybrid but of each parent as well. The work can, of course, be lessened somewhat by the employment of the same parent in more than one combination when such material is available.

The maize hybrids grown in 1912 and 1913 were all from the same female parent, a Chinese type.[1] This is a peculiar corn with a waxy endosperm, received by the Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry, from Shanghai, China. Its water requirement compared with other varieties of maize is relatively high. Various hybrids of this variety were used each year, so that the water requirement of the China type was measured three years in succession. It will be seen that its water requirement in 1913 was much higher than during the two other years. Eleven other species of plants grown at Akron during 1912 and 1913 showed a similar increase in water requirement in 1913, attributable to climatic differences in the two seasons.[2] The variation in water requirement with different seasons does not enter into the present discussion, since only strains that were grown together during the same season are compared.

Of the other varieties tested, Laguna is a Mexican variety grown extensively in Texas, where it has a reputation for drought resistance. Esperanza is a hairy Mexican variety (*Zea hirta* Bonifous) introduced by the Office of Crop Acclimatization and Adaptation Investigations. Hopi is a dwarf variety grown by the Hopi Indians of Arizona, and Pima is a soft corn grown by the Pima Indians at Sacaton, Ariz. Algeria is a slate-colored pop corn the seed of which was imported from Algeria but which came originally from Morocco.[3] Joaquin is an American soft corn from Bradford Island, San Joaquin River, Cal. Budapest is a Hungarian variety of pop corn.

The results of the water-requirement measurements for the individual pots are given in Table I, together with the mean for each series. Six pots were employed in each series in 1912[4] and 1913 and five pots in 1914, which affords a basis for computing the probable error of the mean value obtained.

[1] Collins, G. N. A new type of Indian corn from China. U. S. Dept. Agr. Bur. Plant Indus. Bul. 161, 30 p., 2 pl. 1909.

[2] Briggs, L. J., and Shantz, H. L. Relative water requirement of plants. *In* Jour. Agr. Research, v. 3, no. 1, p. 54. 1914.

[3] Collins, G. N. The value of first-generation hybrids of corn. U. S. Dept. Agr. Bur. Plant Indus. Bul. 191, p. 25. 1910.

——— and Kempton, J. H. Effects of cross-pollination on the size of seed in maize. *In* U. S. Dept. Agr. Bur. Plant Indus. Circ. 124, p. 10. 1913.

[4] With the exception of the Esperanza series, which included only 4 pots.

TABLE I.—*Water requirement of first-generation hybrids of corn and their parent strains at Akron, Colo., in 1912, 1913, and 1914*

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
1912.		*Gm.*	*Kg.*	
Laguna (*Zea mays*), July 2 to Sept. 26	289	376.6	112.4	298
	290	261.2	83.8	321
	291	268.9	84.0	313
	292	448.1	124.4	278
	293	457.4	127.8	279
	294	429.2	119.4	278
Mean		374±27		295±6
China × Laguna (*Zea mays*), June 12 to Sept. 26	271	790.5	224.9	284
	272	500.8	152.2	304
	273	514.0	145.6	283
	274	615.0	179.2	291
	275	571.5	172.8	302
	276	690.0	187.5	272
Mean		614±32		289±4
China (*Zea mays*), June 12 to Sept. 26	265	243.5	84.3	346
	266	577.0	184.6	320
	267	319.0	97.1	304
	268	524.5	173.9	331
	269	660.9	179.6	272
	270	401.5	126.1	314
Mean		454±44		315±7
China × Esperanza (*Zea mays*), June 12 to Sept. 26	259	634.6	151.2	238
	260	638.4	161.3	253
	261	582.8	149.8	257
	262	515.5	133.0	258
	263	583.7	146.5	251
	264	764.0	186.1	244
Mean		618±22		250±2
Esperanza (*Zea mays*), June 12 to Sept. 26	301	492.3	114.3	232
	302	574.7	133.7	233
	303	563.7	141.7	252
	304	510.7	122.7	240
Mean		536±17		239±3
1913.				
Hopi (*Zea mays*), June 14 to Sept. 16	313	346.7	118.8	343
	314	400.0	135.8	340
	315	472.5	170.2	360
	316	417.1	147.0	352
	317	405.3	163.4	403
	318	619.6	185.4	300
Mean		444±27		350±8

TABLE I.—*Water requirement of first-generation hybrids of corn and their parent strains at Akron, Colo., in 1912, 1913, and 1914*—Continued

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
1913.		*Gm.*	*Kg.*	
Hopi×China (*Zea mays*), June 7 to Sept. 16	307	757.2	254.5	336
	308	706.5	257.2	364
	309	712.2	245.5	345
	310	728.1	247.2	340
	311	715.2	246.8	345
	312	716.6	242.0	338
Mean		723±5		345±3
China (*Zea mays*), June 7 to Sept. 16	301	554.9	228.2	411
	302	487.5	210.4	432
	303	492.6	202.3	411
	304	589.2	228.1	387
	305	478.7	198.7	415
	306	523.1	226.6	433
Mean		521±13		415±4
China (*Zea mays*) × Teosinte (*Euchlaena mexicana*), June 7 to Sept. 16	295	661.3	257.9	390
	296	613.2	228.9	373
	297	657.9	239.7	364
	298	654.0	239.3	366
	299	607.5	237.8	391
	300	651.7	244.0	374
Mean		641±17		376±4
Teosinte, Durango (*Euchlaena mexicana*), June 14 to Sept. 16	289	616.4	234.7	380
	290	534.5	211.6	395
	291	624.5	194.0	311
	292	567.3	231.5	408
	293	520.0	214.4	412
	294	421.4	183.2	434
Mean		547±21		390±11
1914.				
Algeria (*Zea mays*), June 3 to Aug 31	238	354.7	117.8	332
	239	521.2	161.1	309
	240	431.3	149.0	346
	241	392.0	131.4	335
	242	386.7	127.8	331
Mean		417±20		331±4
Algeria × China (*Zea mays*), June 3 to Aug. 31	243	515.0	176.3	342
	244	474.2	175.0	369
	245	524.4	178.3	340
	246	573.0	187.6	328
	247	477.5	170.9	358
Mean		512±15		347±5

TABLE I.—*Water requirement of first-generation hybrids of corn and their parent strains at Akron, Colo., in 1912, 1913, and 1914*—Continued

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
1914.		*Gm.*	*Kg.*	
China (*Zea mays*), June 3 to Aug. 31	248	401.3	149.2	372
	249	313.9	104.2	332
	250	394.7	130.9	332
	251	406.7	130.1	320
	252	419.3	143.1	341
Mean		387±12		338±6
Joaquin (*Zea mays*), June 3 to Aug. 31	253	343.3	140.7	410
	254	287.0	91.3	318
	255	[a] 96.3	35.1	364
	256	201.7	74.7	370
	257	301.0	113.6	378
Mean		283±17		368±9
Budapest × Joaquin (*Zea mays*), June 3 to Aug. 31	258	410.3	142.4	347
	259	453.5	159.4	352
	260	382.7	148.9	389
	261	358.0	131.8	368
	262	388.4	143.4	369
Mean		399±11		365±4
Budapest (*Zea mays*), June 3 to Sept. 1	263	427.5	150.2	351
	264	398.3	134.4	337
	265	451.7	150.8	334
	266	379.7	133.2	351
	267	396.7	139.3	351
Mean		411±10		345±4
Budapest × Pima (*Zea mays*), June 3 to Sept. 1	268	368.4	137.4	373
	269	364.8	149.8	411
	270	362.6	144.1	398
	271	364.2	138.4	380
	272	348.5	132.8	381
Mean		362±2		389±5
Pima (*Zea mays*), June 3 to Sept. 1	273	350.7	134.0	382
	274	343.0	132.0	385
	275	375.3	123.2	328
	276	335.2	120.5	360
	277	402.3	149.6	372
Mean		361±9		365±7
Joaquin × Pima (*Zea mays*), June 3 to Sept. 1	278	365.5	151.4	414
	279	388.9	161.2	415
	280	352.3	126.8	360
	281	324.9	121.3	374
	282	433.3	165.2	381
Mean		373±13		389±9

[a] Omitted in calculating the mean.

The results are summarized in Table II, the female parent being given first in each instance. In this table is included also the average water requirement of the two parents, together with the ratio of the water requirement of the hybrid to that of the parental mean. The divergence of the parents—i. e., the ratio of their water requirements—is also given in the last column of the table.

TABLE II.—*Water requirement of hybrid and parent strains of corn*

Year and parent strain.	Water requirement based on dry matter.			Ratio of hybrid to parental mean. $\frac{2c}{a+b}$	$\frac{a}{b}$
	Parent strain.		Hybrid.		
	Observed.	Mean.	Observed.		
1912.					
China	315±7	305±5	289±4	0.95±.02	1.07
Laguna	295±6				
China	315±7	277±4	250±2	.90±.01	1.32
Esperanza	239±3				
1913.					
China	415±4	383±5	345±3	.90±.02	1.19
Hopi	350±8				
China	415±4	403±6	376±4	.93±.02	1.07
Teosinte	390±11				
1914.					
Algeria	331±4	335±4	347±5	1.04±.02	1.02
China	338±6				
Budapest	345±4	357±5	365±4	1.02±.02	1.07
Joaquin	368±9				
Budapest	345±4	355±4	389±5	1.10±.02	1.06
Pima	365±7				
Joaquin	368±9	367±6	389±9	1.06±.03	1.01
Pima	365±7				

Reference to Table II will show that the parents of the hybrids grown in 1912 and 1913 differed in water requirement much more than the parent strains employed in 1914. Each first-generation hybrid of maize grown during the first two years gave a water requirement ranging from 5 to 10 per cent below the mean of its parents. All the maize hybrids grown in 1914 gave a water requirement from 2 to 10 per cent above the mean of the parents. The results of the third year are therefore opposed in direction to those obtained during the first two years.

The parents of the hybrids used in 1912 and 1913 also showed much greater divergence in water requirement than those employed in the 1914 measurements. The question therefore arises as to whether the divergence of the parents may not be a factor in determining the relation of the water requirement of the hybrid to the parental mean.

If we represent the water requirement of the less efficient parent by a, the more efficient parent by b, and the hybrid by c, then the divergence of the parents may be represented by the ratio $\frac{a}{b}$, and the divergence of the hybrid from the mean of its parents by the ratio $\frac{2c}{a+b}$. These ratios are given in Table II. Plotting these values for the eight hybrids under discussion, we obtain a graph of the form given in figure 1. This graph

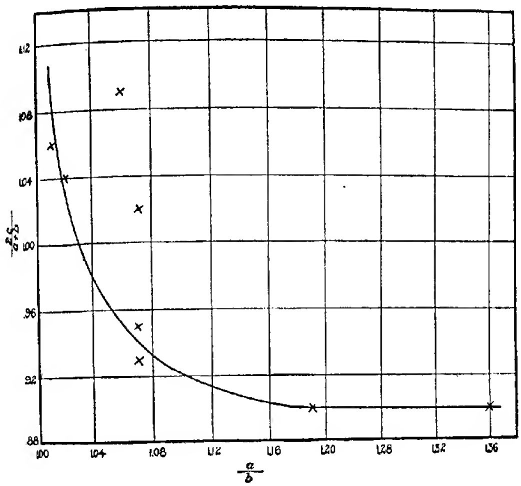


Fig. 1.—Graph showing relation between the parental divergence $\left(\frac{a}{b}\right)$ and the hybrid divergence from the parental mean $\left(\frac{2c}{a+b}\right)$, where a= water requirement of less efficient parent; b= water requirement of more efficient parent; c= water requirement of hybrid.

indicates a correlation between the divergence of the parents and the divergence of the water requirement of the hybrid from the parental mean. There are two outstanding points on this graph, both associated with Budapest pop corn, which in both hybrids is the more efficient parent. If the water requirement of Budapest variety were slightly increased, the points would tend to approach the graph. On the other hand, four of the eight hybrids under consideration have approximately the same parental mean. Therefore, while the data indicate the existence of a relationship between parental divergence and hybrid divergence, this relationship can be expressed quantitatively only by the use of statistical methods which require many more measurements than are now available and more than the practical importance of the subject would justify at this time.

The mean ratio of the water requirement of each hybrid to the average water requirement of its parents is 0.99±0.01. The probable error here refers to the uncertainty of the individual ratios. In using the data as a basis for predicting the probable departure of a hybrid from this ratio, the observed departures must be considered—i. e., the probable error of a single determination must be computed, which is found in this case to be ±0.06. In other words, according to the data at hand, the chances are that the water requirement of a hybrid will not depart from the mean of its parents by more than 6 per cent.

The relative amount of dry matter produced by hybrids and parents is a point of interest in connection with the relative water requirement.[1] In 1912 and 1913 the hybrids produced from 20 to 50 per cent more dry matter than the mean production of the parent strains (Table III). In 1914 three of the hybrids showed an increase in dry matter compared with the parental mean, and one showed a decrease. An analysis of the individual pot yields for both parents and hybrids shows that the pots giving the greatest weight of dry matter usually have a water requirement below the mean of the strain. The greater vegetative vigor of the maize hybrids may therefore be correlated to some extent with the observed reduction in the water requirement below the parental mean.

TABLE III.—*Dry matter produced by hybrid and parent strains of corn*

Year and parent strain.	Mean dry matter.			Ratio of hybrid to parental mean.
	Parent strain.		Hybrid.	
	Observed.	Mean.	Observed.	
1912.				
China	454±44	414±26	614±32	1.48±.12
Laguna	374±27			
China	454±44	495±24	618±22	1.25±.08
Esperanza	536±17			
1913.				
China	521±13	483±15	723±5	1.50±.05
Hopi	444±27			
China	521±13	534±13	641±17	1.20±.04
Teosinte	547±21			
1914.				
Algeria	417±20	402±12	512±15	1.27±.05
China	387±12			
Budapest	411±10	347±10	399±11	1.15±.05
Joaquin	283±17			
Budapest	411±10	386±7	362±2	.94±.02
Pima	361±9			
Joaquin	283±17	322±10	373±13	1.16±.05
Pima	361±9			

[1] Collins has called attention to the marked increase in yield often noted in first generation hybrids of maize. (Collins, G. N. The value of first-generation hybrids in corn. U. S. Dept. Agr. Bur. Plant Indus. Bul. 191, p. 32. 1910.)

The data presented indicate, so far as they are representative of first-generation maize hybrids as a class, that striking differences between the water requirement of hybrids and the mean water requirement of the two parents are not to be expected. The greatest observed departure of the hybrid from the parental mean was ±10 per cent, and, according to the available measurements, the chances are even that first-generation maize hybrids will not depart more than ±6 per cent from the parental mean. This departure, moreover, may take place in either direction—i. e., the hybrid may resemble either parent as regards efficiency in the use of water.

In investigations of this kind more extensive measurements are always desired, both by the reader and the author. To determine with more precision the correlation between hybrids and parents as regards water requirement would necessitate a sufficiently large number of determinations to justify the use of statistical methods. The expense and labor involved in such measurements is great, each determination necessitating the care of from 15 to 18 pots of plants throughout the growing season. Since the results already obtained indicate that hybrids depart but slightly from the mean water requirement of their parents, more extended determinations are not believed to be justified at the present time.

WHEAT HYBRID

The wheat hybrid used was a cross between *Triticum durum* and *Triticum aestivum*. This hybrid strain has been grown for some generations and shows no increase in vegetative vigor as compared with the parent strains. The dry matter produced was practically uniform for parents and hybrid, but the grain yield of the hybrid was below its parents, and this further increases the water requirement of the hybrid when based on grain production.

Reference to Table IV will show that the water requirement of the hybrid is decidedly above both parents (14±1 per cent above the parental mean).

TABLE IV.—*Water requirement of parent and hybrid strains of wheat in 1914*

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirements based on— Grain.	Water requirements based on— Dry matter.
		Gm.	*Gm.*	*Kg.*	*P. ct.*		
Wheat, Iumillo, C. I. 1736 (*Triticum durum*), May 23 to Aug. 11.	67	209.7	83.0	110.4	39	1,330	526
	68	240.7	91.7	129.0	38	1,406	536
	69	252.5	92.7	120.5	37	1,300	477
	70	265.7	98.6	134.8	37	1,367	508
	71	262.3	95.5	125.0	36	1,309	477
	72	334.8	132.1	151.8	39	1,148	454
Mean	......	261±9	......	....	......	1,310±21	496±10

TABLE IV.—*Water requirement of parent and hybrid strains of wheat in 1914*—Contd.

Plant and period of growth.	Pot No.	Dry matter.	Grain.	Water.	Grain.	Water requirements based on—	
						Grain.	Dry matter.
		Gm.	*Gm.*	*Kg.*	*P. ct.*		
Wheat, Iumillo × Preston, May 19 to Aug. 1.	73	283.6	75.0	162.3	26	2,162	572
	74	302.2	91.2	172.6	30	1,895	571
	75	253.6	72.1	147.6	28	2,050	582
	76	225.8	65.6	127.9	29	1,948	567
	77	226.6	67.5	129.6	29	1,921	572
	78	235.9	70.2	136.6	29	1,947	580
Mean	......	255±13	......	......	......	1,987±31	574±2
Wheat, Preston, C. I. 3328 (*Triticum aestivum*), May 23 to Aug. 3.	79	237.4	78.4	118.0	33	1,505	497
	80	261.3	81.1	132.9	31	1,638	508
	81	281.4	94.7	147.8	34	1,561	525
	82	215.8	75.5	110.7	35	1,466	514
	83	249.2	87.0	129.6	35	1,490	520
	84	224.3	79.4	111.7	35	1,407	498
Mean	......	245±10	......	......	......	1,511±22	510±3

EFFECT OF SELF- AND CROSS-POLLINATION

In addition to the maize hybrids Mr. Collins also supplied self-pollinated seed of two individuals, together with cross-pollinated seed from the same individuals. The cross-pollinated plants in this case represent pure seed of the selected strain. Reference to Table V will show that in one instance self-pollination produced no measurable change in the water requirement, while in the other instance an increase in water requirement of 4±1 per cent was observed. The plants from the cross-pollinated seed also gave a higher yield of dry matter. The effect of cross-pollination between individuals is, in this instance at least, quite similar to results produced by the cross-pollination of different strains, so far as water requirement and yield are concerned.

TABLE V.—*Effect of self- and cross-pollination on the water requirement of corn in 1914*

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
		Gm.	*Kg.*	
Corn, German, C24-1 (*Zea mays*), June 3 to Sept. 1.	223	354.4	135.4	382
	224	296.7	107.5	363
	225	333.2	129.8	390
	226	306.4	122.4	399
	227	317.4	125.1	394
Mean	....	322±8	....	386±3

TABLE V.—*Effect of self- and cross-pollination on the water requirement of corn in 1914*—Continued

Plant and period of growth.	Pot No.	Dry matter.	Water.	Water requirement based on dry matter.
		Gm.	*Kg.*	
Corn, German, C24-1x2 (*Zea mays*), June 3 to Sept. 1.	228	419.0	155.6	372
	229	432.4	158.2	366
	230	362.2	136.3	376
	231	357.0	133.7	375
	232	379.5	140.4	370
Mean	....	390±12	....	372±1
Corn, German, C24-2 (*Zea mays*), June 3 to Aug. 31.	233	374.6	143.8	384
	234	407.5	148.2	364
	235	399.8	150.0	376
	236	379.7	139.9	368
	237	335.0	123.2	368
Mean	....	379±9	....	372±2

CONCLUSIONS

Eight first-generation hybrids of maize and one wheat hybrid, together with their parent strains, were included in water-requirement measurements at Akron, Colo., from 1912 to 1914. The hybrids ranged in water requirement from 10 per cent below to 10 per cent above the parental mean. On the basis of the results so far obtained, the chances are even that a maize hybrid will not depart in its water requirement more than ±6 per cent from the parental mean.

Cross-pollination between individual plants of maize leads to results similar to hybridization of different strains, so far as water requirement and yield are concerned.

A wheat hybrid which had been grown for several generations gave a water requirement 14 per cent above the mean water requirement of the parental strains.

PLATE LVIII

First-generation hybrids and parents used in 1912 experiments. The lower leaves of some of these varieties had already matured at the time the photographs were taken and had been picked and placed in the bags attached to the pots.

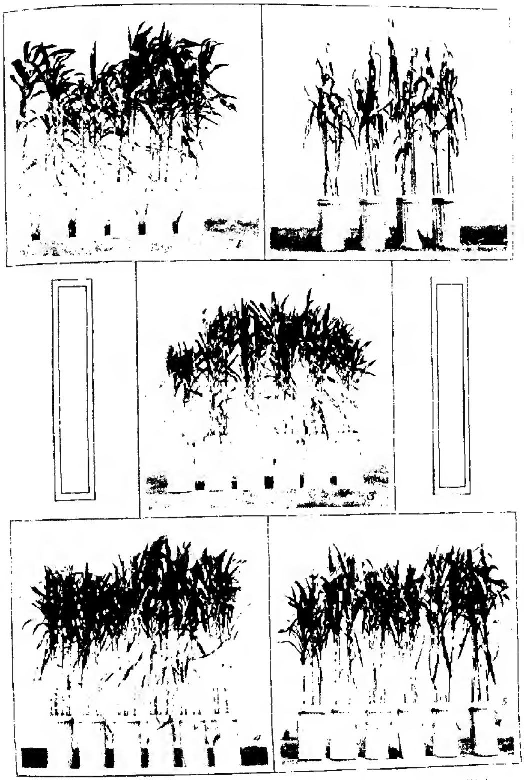
Fig. 1.—Laguna corn (pots 289–294), grown July 2 to September 26, 1912. Photographed on September 9, 1912. Water requirement, 295±6.

Fig. 2.—Esperanza corn (pots 301–304), grown June 12 to September 26, 1912. Photographed on September 7, 1912. Water requirement, 239±3.

Fig. 3.—China corn (pots 265–270), grown June 12 to September 26, 1912. Photographed on September 9, 1912. Water requirement 315±7.

Fig. 4.—Hybrid China × Laguna corn (pots 271–276), grown June 12 to September 26, 1912. Photographed on September 9, 1912. Water requirement 289±4.

Fig. 5.—Hybrid China × Esperanza corn (pots 259–264), grown June 12 to September 26, 1912. Photographed on September 7, 1912. Water requirement, 250±2.



FURTHER STUDIES OF THE EMBRYOLOGY OF TOXOPTERA GRAMINUM

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In 1912 the writer, as junior author,[1] gave in a general way an account of the development of the winter egg of *Toxoptera graminum* Rondani. This is the first time in this country that the development of the winter egg of any species of Aphididae has been followed out beyond the early stages. It was recognized at the time that there was a wide gap in the continuity of the study of this development, which was not represented by the material then at hand. This paper is intended to supply briefly this missing link.

A few eggs were collected in the fall of 1911 and the development was watched carefully in the spring of 1912. This material gave positive evidence that several links were missing in the data previously obtained. Bulletin 110 of the Bureau of Entomology was then in press, and it was too late to do more than indicate where the additional data belonged. As the amount of material obtained in 1911 was rather limited, a large number of eggs were collected in the fall of 1912 for further study. As previously stated,[2] no attempt has been made to treat the subject exhaustively, only the main points in the development being considered.

The same methods of fixation, staining, etc., described in the previous paper[3] were employed.

Turning to Plate VII of Bulletin 110, one will readily see that the gap previously referred to occurs between figures 1 and 2, where the polar organ is entirely lost track of after figure 1. It is also at this point in the development of the embryo that the revolution occurs; hence, there is not a single figure in the first publication to illustrate the revolution of the embryo and the fate of the polar organ.

The polar organ is a unique, newly discovered body, since, so far as the author's information goes, no other observer has heretofore figured any such body; and, while it was exceedingly unfortunate that figures illustrating its fate and the revolution of the embryo could not then be supplied, this serious defect is now eliminated. In view of the necessarily incomplete Plate VII of Bulletin 110, it has been thought best to make an entirely new series of figures covering the same period of development as that covered by Plate VII, drawn from a new series of sections,

[1] Webster, F. M., and Phillips, W. J. The spring grain aphis or "green bug" U. S. Dept. Agr. Bur. Ent. Bul. 110, 153 p., 48 fig., 4 diagr., 9 pl. 1912.

[2] Id., p. 91.

[3] Id., p. 95.

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all of which were cut at the same angle, in this way rendering the continuity more uniform and more easily apparent. The following discussion chiefly relates to the revolution of the embryo, which for reasons already given it was impossible to include in the previous publication.

As the embryo starts from the yolk it approaches the posterior pole of the egg until the amnion in the dorso-cephalic region comes in contact with the serosa, as shown in Plate LIX, figure 1, of this paper. These membranes then unite and the embryo moves forward slightly, as in Plate VII, figure 2.[1]

When the amnion and serosa are in contact, the central cavity of the polar organ still opens upon the surface of the egg. This cavity is filled with some substance that does not take the stains so far used. It is at this time that it is very difficult to remove the shell without also removing the contents of the cavity en masse, as they appear to adhere to the shell. In later stages the cavity is empty and has no opening upon the surface of the egg. From this it would appear that the polar organ does act in an excretory capacity and that its entire contents are eliminated when the embryo begins its revolution, and that it ceases to function after this time.

Figure 3 (Pl. LIX) is slightly more advanced, and it is very apparent that the embryo is starting its revolution. The greater portion of the yolk has now collected at the opposite pole of the egg, and the mesenteron is complete throughout.

Figures 4 and 5 (Pl. LIX) represent the embryo much crumpled and folded upon itself in the act of making its revolution, occupying the entire posterior part of the egg, the yolk having collected in the anterior region. The polar organ is migrating backward. Figure 6 (Pl. LIX) illustrates the embryo after the turn is completed, and the polar organ is on the opposite side of the egg. It will be noted in this figure that the cells are crowding together anterior to the polar organ.

Development from figures 1 to 6 (Pl. LIX) progresses very rapidly, so much of the revolution being accomplished in a few hours. To obtain these stages it was necessary to fix and examine large numbers of eggs every few hours.

Figures 1 to 3, Plate LX, show more advanced stages of the revolution of the embryo and are especially interesting from the fact that they illustrate the fate of the polar organ. It is very apparent that it merges with and loses its identity in the large mass of cells that accumulate in the cephalic region after the revolution of the embryo, which later forms the dorsal organ.

Figures 4 to 6, Plate LX, represent the fate of the dorsal organ after its previous fusion with the polar organ. Under favorable weather conditions the insect will hatch very soon after this point in the development has been reached.

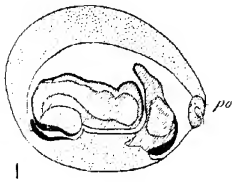
[1] Plate VII, figure 1, of U. S. Dept. Agr. Bur. Ent. Bul. 110 is probably a little misleading, in that it would appear as though the serosa and amnion came in contact in the region of the ventral part of the head, which is not true.

PLATE LIX

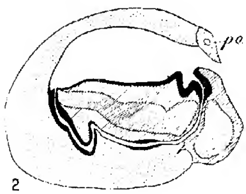
Toxoptera graminum:

Fig. 1–3.—Sagittal sections. Embryo starting revolution. Note changing position of the polar organ, shown at *p. o.* × 83.

Fig. 4–6.—Sagittal sections. Embryo making revolution. Note polar organ, shown at *p. o.*, migrating backward. × 83.



1



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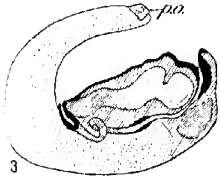

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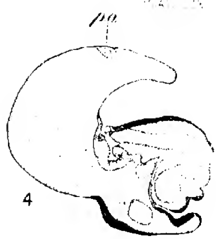

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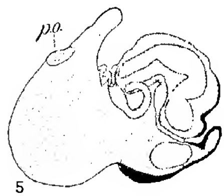

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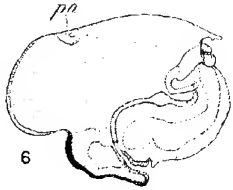

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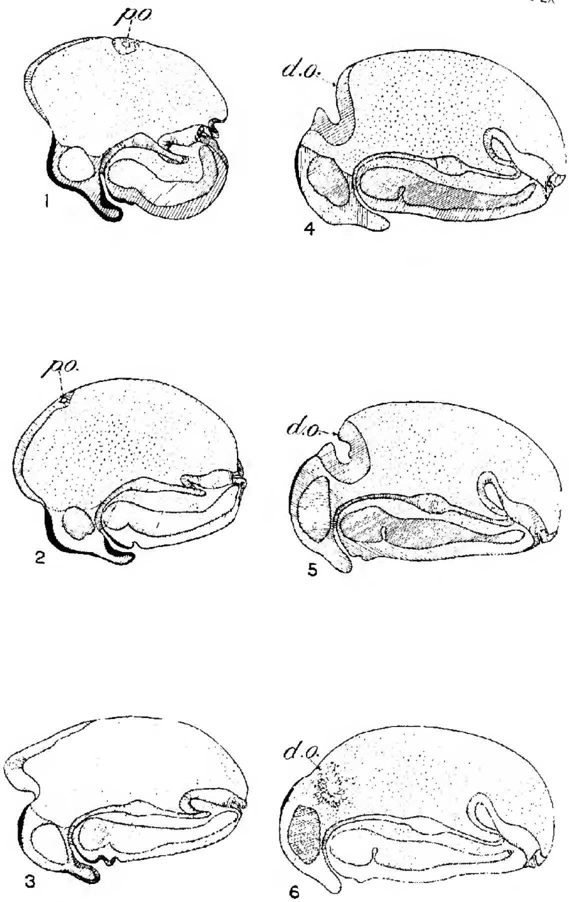
p.o.
d.o.
1
4
p.o.
d.o.
2
5
d.o.
3
6

PLATE LX

Toxoptera graminum:

Fig. 1-3.—Sagittal sections. Revolution is almost complete and shows fate of the polar organ, *p. o.* × 83.

Fig. 4-6.—Sagittal sections. *d. o.*, Dorsal organ. × 83.

PRICKLY-PEARS AS A FEED FOR DAIRY COWS

By T. E. Woodward, *Dairy Husbandman*, and W. F. Turner, *Assistant Dairy Husbandman, Bureau of Animal Industry*, and David Griffiths, *Agriculturist, Office of Farm Management, Bureau of Plant Industry*

INTRODUCTION

Prickly-pears (*Opuntia* spp.) have been fed to cattle for many years in Texas and Mexico, but they have formed only a small part of the ration, and their value as a feed has not been fully appreciated. In the wild state these cacti make a rank growth, and experiments show that they respond readily to cultivation, two years' growth from old stumps yielding as high as 106 tons an acre a year. The average annual yield at Brownsville, Tex., under ordinary cultural conditions for the first two years' growth from cuttings was about 40 tons and at San Antonio, Tex., about 25 tons an acre. The second two years' growth from the cut-over stumps would be still larger. As irrigation of these plants is unnecessary, the cost of growing the crop is very low considering the tonnage produced; and although prickly-pears contain about 90 per cent of water, the production of dry material is large. Since there are no doubts as to the practicability of growing prickly-pears as a farm crop, the only other vital consideration is their feeding value. If it can be shown that they possess sufficient nutrients and have no injurious effect on the animals, there is no reason why these cacti should not come into general use in all sections where they can be readily grown.

One of the writers (Griffiths, 5)[1] conducted a feeding trial for 67 days with two cows at the ranch of Mr. Alexander Sinclair, San Antonio, Tex., and found that these cacti were a palatable and nutritious feed for short periods and that the flavor of the milk was in no way impaired. He also reported the feeding of 20 steers on the ranch of Mr. T. A. Coleman, Encinal, Tex., with a ration of prickly-pear and cottonseed meal for 105 days. Each pound of gain required 55.03 pounds of prickly-pear and 2.5 pounds of cottonseed meal, which was a very satisfactory showing.

Hare (7), of New Mexico, conducted five digestion trials, with two steers in each trial, in which he showed that when the prickly-pear was fed with cured fodders or with grains, the digestibility of both was increased. The five rations that he used were as follows: Prickly-pear (*O. lindheimeri*), prickly-pear (*O. laevis*), prickly-pear and alfalfa, prickly-pear and cottonseed meal, and alfalfa hay.

[1] Reference is made by number to "Literature cited," p. 434.

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Sotgia (10) reported an experiment on feeding prickly-pear to five cows in Sardinia which indicated in general that the prickly-pear increases the milk yield without lowering the percentage of solids in the milk.

On the other hand, Mr. P. R. Mehta (9), Acting Deputy Director of Agriculture, Bombay Presidency, India, in reporting the results of a feeding trial conducted with five animals for five months in 1902, stated:

> The result of our extended and thorough trial proves conclusively that prickly-pear has hardly any value as a cattle feed. It is only when given with a moderate quantity of ordinary fodder that the animals can just manage to live for a period of four to five months.

While these and other interesting and valuable observations on the feeding of the plant have been made, it was thought advisable to obtain more definite knowledge than is afforded by the ordinary feeding practice. Accordingly, the Dairy Division of the Bureau of Animal Industry, cooperating with the Office of Farm Management of the Bureau of Plant Industry, conducted the experiments herein reported at the South Texas Gardens, Brownsville, from October, 1911, to April, 1913.

PLAN OF THE INVESTIGATIONS

CULTIVATION OF PRICKLY-PEAR

The prickly-pears used in these experiments consisted of cuttings of native species collected from uncultivated lands near Brownsville and set out in the cultivated fields of the experimental farm. The stock which it was thought would produce the largest yields was used in the plantings. Three species common to the region were planted, *O. gommei*, *O. cyanella* (color Pl. F), and an unnamed variety. All were probably confined in their distribution to the delta region of the Rio Grande. Although these species differ botanically there is very little distinction between their forage value and that of many other spiny species in southern Texas, except that these delta species are the most viciously spiny and the most difficult to singe. The difficulty in singeing is caused mainly by the large number of coarse spines and the still larger number of long, coarse spicules; and the region being near the coast, where the atmosphere is humid, the spines of all species are less combustible.

The two varieties named constituted probably 95 to 98 per cent of the plantation. The third species differed from these in several particulars, but more especially in its habit of growth. It is judged to be of less value than either of the two others, mainly on account of its smaller, thinner joints. However, this species did not form more than from 3 to 5 per cent of the field.

The main crop of prickly-pear was planted in the spring about 18 months before the feeding was begun and consequently had had two seasons' growth. As the feeding was continuous from the date of beginning,

the material used in these experiments represented the growth of the first, second, and third seasons. The ground was put in a moderate state of tilth, and single-jointed cuttings were set about 30 inches apart in rows. In previous work of the Department at San Antonio and elsewhere, the rows were 6 feet apart, but on account of the greater rapidity of growth at Brownsville, this distance was increased to 8 feet. Moderate cultivation was given for the first year and the early part of the second; but after August of the second season little cultivating could be done, and after September cultivation was abandoned because the plants filled the space between the rows, preventing the horses from passing.

The yields of prickly-pear obtained in this field were not at all typical of what may be expected in this delta region. The plot of ground used was badly infested with Bermuda grass, was flooded considerably during heavy rains, and had three depressions of very stiff Cameron clay running through it. These conditions very materially reduced the yields.

OUTLINE OF THE FIRST YEAR'S TESTS

In selecting materials for use in comparison with prickly-pear, such feeds were chosen as are common to its growing region. It was thought best, therefore, to compare the value of prickly-pear with sorghum hay, sorghum silage, and cottonseed hulls, since these are the feeds which these cacti might replace either wholly or in part. In selecting the animals an effort was made to secure mature but not aged cows that gave evidence of being at least fair milk producers. Accordingly, 13 grade Jersey cows that had been fresh but a few weeks were purchased near Brownsville (Pl. LXII, fig. 2). They were somewhat better than the ordinary Texas dairy stock, and were accustomed to eating prickly-pear. These cows were grouped and fed as shown in Table I.

TABLE I.—*Grouping and rations of cows in first year's tests* [a]

Number of cows in group.	Ration.	
	First period (80 days).	Second period (80 days).
3	Grain, hay, and heavy prickly-pear	Grain, hay, and medium prickly-pear.
3	Grain, hay, and medium prickly-pear	Grain, hay, and heavy prickly-pear.
3 [b]	Grain, hay, and medium prickly-pear	Grain and hay.
3	Grain and hay	Grain, hay, and medium prickly-pear.
1	Cottonseed meal and heavy prickly-pear.	

[a] There was a transition period of 10 days between the two 80-day periods.
[b] One of the cows in this group died; the data for this cow have been disregarded in calculating the results.

The first and second groups were for the comparison of medium and large quantities of prickly-pear as well as the relative values of hay and prickly-pear; the third and fourth groups were for comparing the rela-

tive value of the hay and prickly-pear and the effect of adding prickly-pear to a ration of dry material.

The groups to be compared were balanced as nearly as possible with reference to body weights and yields of milk. In order to do this, records of the milk and fat were kept for a period of 10 days before the cows were divided into groups. The 80-day experimental periods were divided into subperiods of 10 days each, and 10 days were allowed for making the changes in rations at the end of the first 80 days.

The grain mixture consisted of equal parts by weight of corn chop, wheat bran, and cottonseed meal; the hay was sorghum hay of average quality, and the prickly-pear was a very spiny two-years' growth. The prickly-pear was singed in the field with a gasoline torch, then cut off near the ground, and hauled to the cow lot. After being placed in the mangers, the heavier stems were chopped into small pieces with a sharp spade or hoe. The grain was fed according to the amount of milk fat produced, about 10 pounds being supplied for each pound of fat. The milk fat rather than the milk itself, the milk solids, or the energy value of the milk was taken as the basis of feeding, as previous investigations (2) have shown it to be a more reliable guide for this purpose than the whole milk, and perhaps just as reliable as the milk solids or energy value.

As much prickly-pear was fed to the cows of the heavy ration prickly-pear group as they would eat; this varied with the different individuals from 100 to 150 pounds a day. Each cow in the two groups receiving the medium prickly-pear ration received 60 pounds a day, and as much hay was fed to the cows of the four groups as they would consume without undue waste. The quantity varied from 3.5 to 20 pounds, depending upon the individual and the amount of prickly-pear in the ration. In addition to these four groups, one cow received all the prickly-pear she would eat and, in addition, 4 pounds of cottonseed meal daily. The object in this case was to ascertain the physiological effects of feeding large quantities of prickly-pear for a long period.

The body weights of all the cows were controlled by reducing or increasing the roughage so that the gains or losses in weight of the groups to be compared were approximately the same. By conducting the experiment in this manner many of the variable factors were controlled and a direct comparison of the amounts of prickly-pear and hay required to produce a pound of milk fat was made possible.

The body weight of each cow was taken every morning at about the same hour, so that the conditions from day to day as regards fill both of feed and water were as nearly uniform as possible.

The milk was weighed at each milking, and composite samples for fat analysis and specific-gravity determinations were taken for 5 days near the middle of each 10-day period, the samples being preserved with formaldehyde. The milk solids were estimated from the fat and

specific gravity by using Farrington and Woll's table (3, p. 264, tab. 6). At the end of each 10-day period the yield of the milk of each cow was totaled, and the number of pounds of fat for the period was determined. This yield of fat was then used as the basis for computing the grain ration to be fed for the next 10 days.

Every 20 days samples of the ordinary prickly-pear, chopped and thoroughly mixed, were put into quart jars (chloroform being used as a preservative) and sent to the Dairy Division for analysis by Mr. R. H. Shaw.

While this method of determining the relative values of feeds is by no means perfect, it is an improvement on the ordinary feeding experiment, because the factor of live weight was controlled and a direct comparison of the feeds in question made possible on the basis of fat production. It would be well, too, if a comparison could be made on a basis other than that of fat; this, however, owing to the variation in the composition of the milk caused by the feed, is impossible without conducting more experiments. The alternating system of feeding, such as was used in this experiment, favors the poorer feed. If any feed under comparison has a tendency to stimulate production more than another, the cows which receive the better feed for the second period are placed at a disadvantage, as they must begin the second period at a lower level of production than the cows that are to receive the poorer feed. The feeding periods were continued long enough to reduce the experimental error to an insignificant factor.

Cow 7, in the group receiving grain, hay, and the medium prickly-pear ration, died from acute indigestion, but in the opinion of all those connected with the experiment its death can not be ascribed to the prickly-pear any more than to the other ingredients of the ration. In calculating the results of the experiment, therefore, the data for this animal were disregarded.

OUTLINE OF THE SECOND YEAR'S TESTS

As the first-year's work had shown that prickly-pear fed in medium amounts gave best results, it was fed the second year at the rate of 75 pounds a day to each cow in the groups that were used for comparing prickly-pear with other feeds. Two groups were fed to compare the relative values of prickly-pear and the sorghum silage and two to compare the relative values of these cacti and cottonseed hulls; one additional cow was fed to study the effect of prickly-pear when fed for a long period; another cow was fed on prickly-pear without any supplementary ration to ascertain whether it would be possible to maintain an animal upon this feed alone. The cottonseed hulls were such as are ordinarily purchased in the open market. The sorghum silage was below the average in quality, as the sorghum had been sown broadcast and was not fully mature at the time of putting it into the silo. In order to

prevent the silage from spoiling, five cows were used in each group fed silage, although there were only three animals in the other groups.

For the second year's work grade Jersey cows, comparable with those used in the first year's experiments, were purchased from the same source. The 18 cows used were grouped and fed as follows (Table II):

TABLE II.—*Grouping and rations of cows in second year's tests* [a]

Number of cows in group.	Ration. First period (80 days).	Ration. Second period (80 days).
5	Grain, cottonseed hulls, and medium prickly-pear.	Grain, cottonseed hulls, and sorghum silage.
5	Grain, cottonseed hulls, and sorghum silage.	Grain, cottonseed hulls, and medium prickly-pear.
3	Grain, cottonseed hulls, and medium prickly-pear.	Grain and cottonseed hulls.
3	Grain and cottonseed hulls	Grain, cottonseed hulls, and medium prickly-pear.
1	Cottonseed meal and prickly-pear *ad libitum*.	
1	Prickly-pear alone.	

[a] There was a transition period of 10 days between the two 80-day periods.

Cow 5 in the first group, a heavy-producing cow that had a roughage ration of cottonseed hulls, became so ill that it was necessary to change the character of her ration at the end of 70 days in the first 80-day period. With this individual the second feeding period was cut from 80 to 70 days, so as to make a better comparison of the data obtained from the two periods. With all the other animals the data were collected for the full periods of 80 days each.

The digestible nutrients of the feeds in the first year's trials were estimated from actual digestion trials. (See p. 418.) As no digestion trials of the feed used during the second year's work were made, the coefficients of digestion used in calculating the nutrients digested were taken from Henry (8, pp. 572–577), except for prickly-pear, in which case our own figures were used. The energy values were calculated by the Armsby (1) method.

EXPERIMENTAL WORK

MILK PRODUCTION, FEEDS, AND BODY WEIGHTS

The principal data by groups, showing in comparative form the results of feeding the various rations, are given in Tables III to VI. Table III deals with milk production, including the fat and solid contents of the milk; Table IV shows the amount of each of the feeds consumed and the body weights; Table V, the nutrients digested; and Table VI, the energy values of the feed consumed. Complete data for the individual animals will be found in Tables XX to XLII.

TABLE III.—*Effect of different feeds on milk production*

FIRST YEAR

Group.	Nos. of cows.	80-day period.	Total milk.	Fat.		Total solids.
				Average per cent.	Total quantity.	
			Pounds.	*Per cent.*	*Pounds.*	*Pounds.*
Heavy prickly-pear	1, 2, 3	First	3,716.0	3.90	144.87	475.97
Medium prickly-pear	4, 5, 6	...do	4,676.6	4.42	200.53	630.82
Heavy prickly-pear	4, 5, 6	Second	4,442.3	3.93	174.76	568.41
Medium prickly-pear	1, 2, 3	...do	3,206.8	4.14	132.91	416.06
Total for heavy prickly-pear groups.	1, 2, 3 4, 5, 6	First Second	8,158.3	3.92	319.63	1,044.38
Total for medium prickly-pear groups.	4, 5, 6 1, 2, 3	First Second	7,883.4	4.31	339.44	1,046.88
Medium prickly-pear	8, 9	First	3,543.1	3.81	135.10	441.81
Sorghum hay	10, 11, 12	...do	4,611.3	4.87	224.55	654.87
Medium prickly-pear	10, 11, 12	Second	4,385.8	4.33	189.98	588.78
Sorghum hay	8, 9	...do	3,230.8	4.04	130.69	409.62
Total for medium prickly-pear groups.	8, 9 10, 11, 12	First Second	7,928.9	4.10	325.08	1,033.59
Total for hay groups	10, 11, 12 8, 9	First Second	7,842.1	4.53	355.24	1,064.49

SECOND YEAR

Group.	Nos. of cows.	80-day period.	Total milk.	Average per cent.	Total quantity.	Total solids.
Medium prickly-pear	6, 9, 15, 16, 18	First	8,804.1	4.29	377.68	1,157.70
Sorghum silage	3, 14, 17, 19, 20	...do	7,638.5	5.14	392.86	1,103.93
Medium prickly-pear	3, 14, 17, 19, 20	Second	6,817.6	4.74	323.41	975.87
Sorghum silage	6, 9, 15, 16, 18	...do	7,649.0	4.72	360.92	1,084.74
Total for medium prickly-pear groups.	6, 9, 15, 16, 18 3, 14, 17, 19, 20	First Second	15,621.7	4.48	701.09	2,133.57
Total for sorghum-silage groups	3, 14, 17, 19, 20 6, 9, 15, 16, 18	First Second	15,287.5	4.93	753.78	2,188.67
Medium prickly-pear	8, 11, 12	First	6,354.4	4.56	289.80	875.26
Cottonseed hulls [a]	4, 5, 10	...do	6,075.2	4.90	298.00	857.44
Medium prickly-pear [a]	4, 5, 10	Second	4,550.2	4.43	201.66	618.48
Cottonseed hulls	8, 11, 12	...do	5,189.8	4.97	258.20	737.39
Total for medium prickly-pear groups.[a]	8, 11, 12 4, 5, 10	First Second	10,904.6	4.51	491.46	1,493.74
Total for cottonseed-hulls groups	4, 5, 10 8, 11, 12	First Second	11,265.0	4.94	556.20	1,594.83

[a] Cow 5: 70-day period.

TABLE IV.—*Effect of feeds consumed on body weights of dairy cows*

FIRST YEAR

Group.	Nos. of cows.	80-day period.	Feed consumed.				
			Grain	Sorghum hay.	Cottonseed hulls.	Prickly-pear.	Sorghum silage.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Heavy prickly-pear	1, 2, 3	First	1,380.0	1,177.5	....	34,451	....
Medium prickly-pear	4, 5, 6	...do	1,923.0	2,401.0	....	17,795	....
Heavy prickly-pear	4, 5, 6	Second	1,790.0	995.5	....	27,248	....
Medium prickly-pear	1, 2, 3	...do	1,452.6	2,113.5	....	14,400	....
Total for heavy prickly-pear groups	1, 2, 3 4, 5, 6	First Second	3,170.0	2,173.0	....	61,699	....
Total for medium prickly-pear groups.	4, 5, 6 1, 2, 3	First Second	3,375.6	4,514.5	....	32,195	....
Medium prickly-pear	8, 9	First	1,288.0	1,321.5	....	11,880	....
Sorghum hay	10, 11, 12	...do	2,088.6	4,165.5	....	....	....
Medium prickly-pear	10, 11, 12	Second	1,888.9	2,049.5	....	14,400	....
Sorghum hay	8, 9	...do	1,379.1	2,396.5	....	....	....
Total for medium prickly-pear groups.	8, 9 10, 11, 12	First Second	3,176.9	3,371.0	....	26,280	....
Total for hay groups	10, 11, 12 8, 9	First Second	3,467.7	6,562.0	....	....	....

TABLE IV.—*Effect of feeds consumed on body weights of dairy cows*—Continued

SECOND YEAR

Group.	Nos. of cows.	80-day period.	Feed consumed. Grain.	Feed consumed. Sorghum hay.	Feed consumed. Cottonseed hulls.	Feed consumed. Prickly-pear.	Feed consumed. Sorghum silage.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Medium prickly-pear	6, 9, 15, 16, 18	First	3,811.0	....	3,886	29,975	....
Sorghum silage	3, 14, 17, 19, 20	...do	3,894.0	....	3,874	....	10,849.5
Medium prickly-pear	3, 14, 17, 19, 20	Second	3,301.9	....	3,540	29,240	....
Sorghum silage	6, 9, 15, 16, 18	...do	3,685.1	....	3,998	....	8,499.0
Total for medium prickly-pear groups.	6, 9, 15, 16, 18 3, 14, 17, 19, 20	First Second	7,112.9	....	7,426	59,215	....
Total for sorghum-silage groups	3, 14, 17, 19, 20 6, 9, 15, 16, 18	First Second	7,579.1	....	7,872	....	19,348.5
Medium prickly-pear	8, 11, 12	First	3,181.0	....	2,080	17,080	....
Cottonseed hulls [a]	4, 5, 10	...do	3,220.7	....	4,577	....	....
Medium prickly-pear [a]	4, 5, 10	Second	2,086.0	....	1,884	16,677	....
Cottonseed hulls	8, 11, 12	...do	2,683.0	....	4,244	....	....
Total for medium prickly-pear groups.[a]	8, 11, 12 4, 5, 10	First Second	5,267.0	....	3,964	33,757	....
Total for cottonseed-hulls groups [a]	4, 5, 10 8, 11, 12	First Second	5,903.7	....	8,821	....	....

FIRST YEAR

Group.	Nos. of cows.	80-day period.	Body weight. Initial weight.	Body weight. Final weight.	Body weight. Gain.
			Pounds.	*Pounds.*	*Pounds.*
Heavy prickly-pear	1, 2, 3	First	2,263.0	2,327.8	64.8
Medium prickly-pear	4, 5, 6	...do	2,215.2	2,309.4	94.2
Heavy prickly-pear	4, 5, 6	Second	2,389.2	2,421.6	32.4
Medium prickly-pear	1, 2, 3	...do	2,216.6	2,213.2	−3.4
Total for heavy prickly-pear groups	1, 2, 3 4, 5, 6	First Second	4,652.2	4,749.4	97.2
Total for medium prickly-pear groups.	4, 5, 6 1, 2, 3	First Second	4,431.8	4,522.6	90.8
Medium prickly-pear	8, 9	First	1,315.5	1,389.8	74.3
Sorghum hay	10, 11, 12	...do	1,961.1	2,052.6	91.5
Medium prickly-pear	10, 11, 12	Second	2,079.2	2,101.6	22.4
Sorghum hay	8, 9	...do	1,397.2	1,381.2	−16.0
Total for medium prickly-pear groups.	8, 9 10, 11, 12	First Second	3,394.7	3,491.4	96.7
Total for hay groups	10, 11, 12 8, 9	First Second	3,358.3	3,433.8	75.5

SECOND YEAR

Group.	Nos. of cows.	80-day period.	Initial weight.	Final weight.	Gain.
Medium prickly-pear	6, 9, 15, 16, 18	First	3,936.2	4,070.8	134.6
Sorghum silage	3, 14, 17, 19, 20	...do	3,948.2	4,116.0	167.8
Medium prickly-pear	3, 14, 17, 19, 20	Second	4,259.0	4,262.2	3.2
Sorghum silage	6, 9, 15, 16, 18	...do	4,028.2	3,995.2	−33.0
Total for medium prickly-pear groups.	6, 9, 15, 16, 18 3, 14, 17, 19, 20	First Second	8,195.2	8,333.0	137.8
Total for sorghum-silage groups	3, 14, 17, 19, 20 6, 9, 15, 16, 18	First Second	7,976.4	8,111.2	134.8
Medium prickly-pear	8, 11, 12	First	2,352.0	2,406.0	55.0
Cottonseed hulls [a]	4, 5, 10	...do	2,412.0	2,436.6	24.6
Medium prickly-pear [a]	4, 5, 10	Second	2,429.8	2,469.4	39.6
Cottonseed hulls	8, 11, 12	...do	2,349.2	2,419.8	70.6
Total for medium prickly-pear groups.[a]	8, 11, 12 4, 5, 10	First Second	4,780.8	4,875.4	94.6
Total for cottonseed-hulls groups [a]	4, 5, 10 8, 11, 12	First Second	4,761.2	4,856.4	95.2

[a] Cow 5: 70-day period.

TABLE V.—*Amount of nutrients digested by dairy cows on different rations*

FIRST YEAR

Ration.	Nos. of cows.	80-day period.	Dry matter.	Protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Heavy prickly-pear.....	1, 2, 3	First....	3,155.85	609.78	506.66	1,543.49	109.60
Medium prickly-pear...	4, 5, 6	...do.....	3,171.38	530.83	607.80	1,666.07	145.05
Heavy prickly-pear.....	4, 5, 6	Second..	3,584.97	617.26	383.36	1,918.23	164.95
Medium prickly-pear...	1, 2, 3	...do....	3,106.37	595.69	529.32	1,772.44	147.35
Total for heavy prickly-pear groups.	1, 2, 3 4, 5, 6	First.... Second..	6,740.82	1,227.04	890.02	3,461.72	274.55
Total for medium prickly-pear groups.	4, 5, 6 1, 2, 3	First.... Second..	6,277.75	926.52	1,137.12	3,438.51	292.40
Medium prickly-pear...	8, 9	First....	2,010.86	349.31	362.39	1,060.90	94.09
Sorghum hay..........	10, 11, 12	...do.....	3,047.02	511.84	731.23	1,541.28	161.24
Medium prickly-pear...	10, 11, 12	Second..	3,309.40	476.18	531.73	1,916.57	177.47
Sorghum hay..........	8, 9	...do....	2,206.67	318.93	491.27	1,208.67	129.94
Total for medium prickly-pear groups.	10, 11, 12 8, 9	Second.. First....	5,380.26	825.49	894.12	2,977.47	271.56
Total for hay groups.	10, 11, 12 8, 9	...do..... Second..	5,253.09	830.77	1,222.50	2,749.95	291.18

SECOND YEAR

Ration.	Nos. of cows.	80-day period.	Dry matter.	Protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Medium prickly-pear...	6, 9, 15, 16, 18	First....	5,601.60	843.01	1,016.80	3,198.84	207.88
Sorghum silage.........	3, 14, 17, 19, 20	...do....	5,806.49	882.53	1,313.82	3,019.28	260.27
Medium prickly-pear...	3, 14, 17, 19, 20	Second..	4,818.52	745.48	939.78	2,679.92	175.86
Sorghum silage.........	6, 9, 15, 16, 18	...do....	5,317.34	825.97	1,222.94	2,734.04	242.29
Total for medium prickly-pear groups.	6, 9, 15, 16, 18 3, 14, 17, 19, 20	First.... Second..	10,420.12	1,588.49	1,956.58	5,878.76	383.74
Total for sorghum silage.	3, 14, 17, 19, 20 6, 9, 15, 16, 18	First.... Second..	11,123.83	1,708.50	2,536.76	5,753.92	502.56
Medium prickly-pear...	8, 11, 12	First....	3,867.15	684.32	568.62	2,251.82	159.68
Cottonseed hulls[a]......	4, 5, 10	...do.....	4,071.76	665.07	1,039.84	2,026.90	173.88
Medium prickly-pear[a]..	4, 5, 10	Second..	2,838.98	466.14	510.84	1,595.67	107.94
Cottonseed hulls........	8, 11, 12	...do.....	3,513.62	556.47	979.58	1,695.86	136.91
Total for medium prickly-pear groups.[a]	8, 11, 12 4, 5, 10	First.... Second..	6,706.13	1,150.46	1,079.46	3,847.49	267.62
Total for cottonseed-hulls groups.[a]	4, 5, 10 8, 11, 12	First.... Second..	7,585.38	1,219.54	2,019.42	3,722.76	310.79

[a] Cow No. 5: 70-day period.

TABLE VI.—*Energy value of feed consumed by dairy cows on different rations*

FIRST YEAR

Group.	Nos. of cows.	80-day period.	Cottonseed meal.	Wheat bran.	Corn chop.	Prickly-pear.
			Therms.	*Therms.*	*Therms.*	*Therms.*
Heavy prickly-pear..............	1, 2, 3	First....	389.05	212.44	360.72	1,210.81
Medium prickly-pear............	4, 5, 6	...do.....	512.17	302.18	532.95	666.94
Heavy prickly-pear..............	4, 5, 6	Second..	549.73	285.52	464.73	1,307.31
Medium prickly-pear............	1, 2, 3	...do	427.28	236.74	400.00	740.05
Total for heavy prickly-pear groups.	1, 2, 3 4, 5, 6	First.... Second..	938.78	497.96	825.45	2,518.12
Total for medium prickly-pear groups.	4, 5, 6 1, 2, 3	First.... Second..	939.45	538.92	932.95	1,406.99
Medium prickly-pear............	8, 9	First....	343.02	202.36	356.92	445.28
Sorghum hay.....................	10, 11, 12	...do.....	569.62	328.72	572.47	....
Medium prickly-pear............	10, 11, 12	Second..	555.59	307.83	520.15	740.05
Sorghum hay.....................	8, 9	...do.....	414.75	225.12	375.78	....
Total for medium prickly-pear groups.	8, 9 10, 11, 12	First.... Second..	898.61	510.19	877.07	1,185.33
Total for hay groups......	10, 11, 12 8, 9	First Second..	984.37	553.84	948.25	....

TABLE VI.—*Energy value of feed consumed by dairy cows on different rations*—Continued

SECOND YEAR

Group.	Nos. of cows.	80-day period.	Cotton-seed meal.	Wheat bran.	Corn chop.	Prickly-pear.
			Therms.	*Therms.*	*Therms.*	*Therms.*
Medium prickly-pear	6, 9, 15, 16, 18	First	995.21	635.84	1,129.07	1,191.55
Sorghum silage	3, 14, 17, 19, 20	...do	1,016.90	649.72	1,153.69	....
Medium prickly-pear	3, 14, 17, 19, 20	Second	809.39	550.02	962.45	980.46
Sorghum silage	6, 9, 15, 16, 18	...do	903.45	613.87	1,074.20	....
Total for medium prickly-pear groups.	6, 9, 15, 16, 18	First	1,804.60	1,185.86	2,091.52	2,172.01
	3, 14, 17, 19, 20	Second				
Total for sorghum silage groups.	6, 9, 15, 16, 18	...do	1,920.35	1,263.59	2,227.89	....
	3, 14, 17, 19, 20	First				
Medium prickly-pear	8, 11, 12	...do	830.68	530.74	942.41	678.94
Cottonseed hulls[a]	4, 5, 10	...do	841.11	537.39	954.24	....
Medium prickly-pear[a]	4, 5, 10	Second	511.35	347.47	608.02	559.18
Cottonseed hulls	8, 11, 12	...do	657.72	446.92	782.03	....
Total for medium prickly-pear groups.[a]	8, 11, 12	First	1,342.03	878.21	1,550.43	1,238.12
	4, 5, 10	Second				
Total for cottonseed-hulls groups.[a]	4, 5, 10	First	1,498.83	984.31	1,736.27	....
	8, 11, 12	Second				

FIRST YEAR

Group.	Nos. of cows.	80-day period.	Sorghum silage.	Sorghum hay.	Cotton-seed hulls.	Total energy.
			Therms.	*Therms.*	*Therms.*	*Therms.*
Heavy prickly-pear	1, 2, 3	First	....	264.17	....	2,457.19
Medium prickly-pear	4, 5, 6	...do	....	613.10	....	2,627.34
Heavy prickly-pear	4, 5, 6	Second	....	337.61	....	2,941.90
Medium prickly-pear	1, 2, 3	...do	....	811.03	....	2,615.10
Total for heavy prickly-pear groups.	1, 2, 3	First	....	601.78	....	5,382.09
	4, 5, 6	Second				
Total for medium prickly-pear groups.	4, 5, 6	First	....	1,424.13	....	5,242.44
	1, 2, 3	Second				
Medium prickly-pear	8, 9	First	....	337.44	....	1,685.02
Sorghum hay	10, 11, 12	...do	....	1,072.17	....	2,542.98
Medium prickly-pear	10, 11, 12	Second	....	787.49	....	2,911.11
Sorghum hay	8, 9	...do	....	920.35	....	1,936.00
Total for medium prickly-pear groups.	8, 9	First	....	1,124.93	....	4,596.13
	10, 11, 12	Second				
Total for hay groups	10, 11, 12	First	....	1,992.52	....	4,478.98
	8, 9	Second				

SECOND YEAR

Medium prickly-pear	6, 9, 15, 16, 18	First	....	....	422.98	4,373.95
Sorghum silage	3, 14, 17, 19, 20	...do	1,180.51	....	424.48	4,425.30
Medium prickly-pear	3, 14, 17, 19, 20	Second	....	....	365.14	3,667.46
Sorghum silage	6, 9, 15, 16, 18	...do	965.52	....	412.36	3,909.40
Total for medium prickly-pear groups.	6, 9, 15, 16, 18	First	....	....	787.42	8,041.41
	3, 14, 17, 19, 20	Second				
Total for sorghum silage groups.	6, 9, 15, 16, 18	...do	2,146.03	....	836.84	8,394.70
	3, 14, 17, 19, 20	First				
Medium prickly-pear	8, 11, 12	...do	....	....	227.92	3,210.69
Cottonseed hulls[a]	4, 5, 10	...do	....	....	501.55	2,834.29
Medium prickly-pear[a]	4, 5, 10	Second	....	....	194.33	2,220.35
Cottonseed hulls	8, 11, 12	...do	....	....	437.78	2,324.45
Total for medium prickly-pear groups.[a]	8, 11, 12	First	....	....	422.25	5,431.04
	4, 5, 10	Second				
Total for cottonseed-hulls groups.[a]	4, 5, 10	First	....	....	939.33	5,158.74
	8, 11, 12	Second				

[a] Cow No. 5, 70-day period.

Tables III to VI show in general that prickly-pear produced more milk with a smaller percentage of fat than the other feeds with which it was compared. The total production of milk fat was reduced appreciably by feeding prickly-pear, while the production of milk solids was lowered but slightly.

In comparing the results of the first year's work, it will be noticed that the heavy prickly-pear ration produced more milk and less fat but the same amount of total solids as the medium prickly-pear ration. It will be seen also that the dry matter digested and the energy values of the feed were greater in the case of the heavy ration.

It will be observed that the medium prickly-pear ration produced slightly more milk but less fat and total solids than the sorghum-hay group. The cows also consumed more digestible nutrients, and the energy values were greater. While the body weights were not so well controlled as with the preceding groups, it is thought that the error on this account is of no great consequence.

Cows fed with prickly-pear produced a little more milk but less fat and less other solids than those fed on the sorghum silage. The cows of the sorghum-silage groups ate more digestible dry matter, and the energy value of their feed was greater.

The results in the test of medium rations of prickly-pear as compared with cottonseed hulls are somewhat different from the preceding. The cottonseed hulls not only produced more fat but also more milk and total solids than prickly-pear. There was more digestible dry matter in the ration of the cottonseed-hulls groups, but a smaller energy value.

The results as a whole seem to show that a moderate ration of prickly-pear was used more efficiently than a heavy ration. As will be seen later, the digestion of dry matter is lower for the heavy ration, and possibly the cows receiving a large amount of prickly-pear required more food for maintenance, especially in cold weather.

Ordinarily it would be better to feed a medium rather than a heavy ration of prickly-pear to milking cows because of the greater fat production and the more sanitary condition of the cows and stable. Prickly-pear in large quantities loosens the bowels, which makes it difficult to keep the cows clean. There are many cases, however, in which a large amount of these cacti might well be fed. If the product is to be disposed of as milk rather than as butter or cream and if supplementary roughages are relatively high in cost, it would be to the advantage of the dairyman to feed a large quantity of prickly-pear, provided extra precautions are taken to keep the cows and the stable clean. The proper amount to feed depends to some extent upon the ability of the individual animal to consume large quantities. It is thought that most cows will refuse to eat more than 100 pounds each day when supplemented with grain and a small amount of hay.

RELATIVE NUTRITIVE VALUE OF THE FEEDS

The following calculations show the method employed in estimating the relative nutritive values. To obtain the number of pounds of feed required to produce one pound of fat, the total number of pounds of feed was divided by the total fat production. The quantity of prickly-pear used to replace the hay or other feed was considered equal in value for fat production to the amount of feed which it replaced. The same method was followed in estimating the relative values of the different feeds on the bases of nutrients digested and energy values. The results are given in Table VII.

Table VIII contains different methods for comparing the relative nutritive value of the feeds tested, estimated from their chemical composition and digestibility. If the digestible nutrients or therms furnished an accurate means of estimating the relative values of different kinds of feeds, 1 pound of digestible nutrients or 1 therm in one kind of feed would be equivalent in producing power to 1 pound of digestible nutrients or 1 therm in another kind of feed. Thus, while 1.40 pounds of digestible nutrients in prickly-pear are equivalent to 1 pound of digestible nutrients in sorghum hay, 0.90 of a pound in the prickly-pear is equal to 1 pound in the cottonseed hulls, and while 1.61 therms in the prickly-pear are equal to 1 therm in the hay, 3.03 therms are required to equal 1 therm in cottonseed hulls. The digestible-nutrients method shows less variation than the energy-value method and for this reason is more accurate, in this investigation at least, but both show such wide variations as to make them of doubtful value in estimating the nutritive values.

On account of the variation in the water content of prickly-pear and sorghum hay, it was thought best to reduce them all to a dry-matter content that would be near the average for the particular feed. The relative values were estimated by using the following percentages of dry matter for the various feeds: Prickly-pear, 10 per cent; sorghum hay, 80 per cent; cottonseed hulls, 90 per cent; silage, 25 per cent. Calculated in this way, the relative values on the basis of feed consumed are as follows:

Medium prickly-pear and sorghum hay versus heavy prickly-pear and sorghum hay 1	pound of sorghum hay equals 15.9 pounds of prickly-pear.
Medium rations of prickly-pear versus sorghum hay............. 1	pound of sorghum hay equals 10.1 pounds of prickly-pear.
Medium rations of prickly-pear versus sorghum silage............ 1	pound of sorghum silage equals 2.6 pounds of prickly-pear.
Medium rations of prickly-pear versus cottonseed hulls 1	pound of cottonseed hulls equals 5.8 pounds of prickly-pear.

The prickly-pear used in these experiments contained perhaps more water than the average. Henry (8, p. 572-577) gives the water content of prickly-pear as 84.2 per cent, and Hare's (7) average of several analyses of a certain variety shows these cacti to have 83.41 per cent of water. Prickly-pear containing these percentages of water would be worth probably 50 or 60 per cent more than is last indicated.

TABLE VII.—*Relative values of sorghum hay and prickly-pear when the latter is fed in medium quantities*

ON BASIS OF FEED CONSUMED

Group.	Fat produced.	Total feed consumed.			Feed required for 1 pound of fat.		
		Grain.	Sorghum hay.	Prickly-pear.	Grain.	Sorghum hay.	Prickly-pear.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Medium prickly-pear	325.08	3,176.9	3,371.0	26,280.0	9.8	10.37	80.84
Sorghum hay [a]	355.24	3,467.7	6,562.0	....	9.8	18.47	....

ON BASIS OF NUTRIENTS DIGESTED

Group.	Fat produced.	Total nutrients digested.			Digestible nutrients required for 1 pound of fat.		
		Grain.	Sorghum hay.	Prickly-pear.	Grain.	Sorghum hay.	Prickly-pear.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Medium prickly-pear	325.08	2,101.70	1,543.75	1,323.19	6.5	4.75	4.07
Sorghum hay [b]	355.24	2,300.84	2,793.56	....	6.5	7.86	....

ON BASIS OF ENERGY VALUE

Group.	Fat produced.	Total energy in nutrients digested.			Energy required for 1 pound of fat.		
		Grain.	Sorghum hay.	Prickly-pear.	Grain.	Sorghum hay.	Prickly-pear.
	Pounds.	*Therms.*	*Therms.*	*Therms.*	*Therms.*	*Therms.*	*Therms.*
Medium prickly-pear	325.08	2,285.87	1,124.93	1,185.33	7.0	3.46	3.65
Sorghum hay [c]	355.24	2,486.46	1,992.52	....	7.0	5.61	....

[a] Quantity of hay required to replace 80.84 pounds of prickly-pear=18.47−10.37=8.10 pounds.
One pound of sorghum hay equals 10 pounds of prickly-pear.
[b] Quantity of digestible nutrients in hay required to replace 4.07 pounds digestible nutrients in prickly-pear is 7.86−4.75=3.11 pounds.
One pound of digestible nutrients in the hay equals 1.31 pounds digestible nutrients in prickly-pear.
[c] One therm in the hay equals 1.70 therms in the prickly-pear.

TABLE VIII.—*Relative values of prickly-pear and other feeds*

Basis of comparison.	Medium prickly-pear and sorghum hay v. heavy prickly-pear and hay.		Medium prickly-pear v. sorghum hay.		Medium prickly-pear v. sorghum silage.		Medium prickly-pear v. cottonseed hulls.	
	Sorghum hay.	Prickly-pear.	Sorghum hay.	Prickly-pear.	Sorghum silage.	Prickly-pear.	Cotton-seed hulls.	Prickly-pear.
Feed consumed, pounds	1	15.1	1	10.0	1	3.3	1	8.8
Nutrients digested, pounds	1	1.4	1	1.31	1	1.02	1	.90
Energy values, therms	1	1.61	1	1.70	1	1.09	1	3.03

DIGESTION TRIALS

Toward the close of the first year's work it became apparent that the heavy prickly-pear ration was not used as efficiently as the medium. In order to ascertain whether the heavy ration was rushed through the digestive tract too rapidly to allow sufficient time for digestion and absorption, and also to check previous work of that kind which had not been altogether satisfactory, some digestion trials were conducted in May and June, using cows that were accustomed to the different classes of roughage fed during the previous year's work.

The plan was to use two cows in each trial and to conduct five trials for a period of 10 days each, with a preliminary period of 4 to 7 days during which time the ration was to be exactly the same in kind and quantity as during the digestion trial. This plan was rigidly adhered to, except that in one of the trials data for 9 days instead of 10 were used.

The four different rations used were as follows: Sorghum hay and grain; sorghum hay, medium quantities of prickly-pear, and grain; sorghum hay, heavy rations of prickly-pear, and grain; and prickly-pear alone. The grain in every case consisted of equal parts by weight of corn meal, cottonseed meal, and wheat bran.

The sorghum hay was run through a cutter, thoroughly mixed, and a sample taken for analysis. Samples of the corn meal and other grains were taken before the grain mixture was prepared. The prickly-pear was sampled by taking a representative portion each day, chopping it into fine pieces, mixing and weighing out about 100 gm. on a chemical balance. This portion was then dried on a hot-water bath. The dried samples for 10 days were placed together in a tight jar and sent to Washington for analysis with the other samples.

The feces were collected by attendants who were with the cows day and night throughout the trials. No urine was collected. The cows were kept in ordinary rigid stanchions. The wooden gutter behind and the rear portion of the platform on which the cows stood were covered with white oilcloth, so that in case the attendant failed to catch the feces at the time they were passed, they could be easily collected from the cloth. In order to avoid any possibility of including urine with the feces, water was used to wash it out of the gutter. An ordinary shovel was used in catching the feces, except in the case of the cows receiving prickly-pear alone, when, owing to the extreme looseness of the bowels, it became necessary to use a large tub. The feces were placed in large cans, weighed each day at the same hour, and, after being thoroughly mixed, an aliquot portion was taken and composited for chemical analysis. These samples were preserved with chloroform and kept on ice. At the end of 10 days a portion of the composite was weighed on the chemical balances and then dried over the hot-water bath in the same way as the prickly-pear. Owing to the loss in nitrogen when feces are dried, the samples for nitrogen deter-

mination were taken from the fresh material, preserved with chemically pure sulphuric acid, and sent to the Washington laboratories for analysis.

Table IX gives coefficients of digestion for each animal in the different trials, together with the character of the ration and the amounts of each feed fed. Complete data for each individual animal will be found in Tables XX to XLII.

TABLE IX.—*Summary of coefficients of digestion for dairy cows*

No. of cow.	Ration.			Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Organic matter.
	Grain.	Sorghum hay.	Prickly-pear.							
	Lbs.	*Lbs.*	*Lbs.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11	66	180	....	61.75	23.97	64.60	65.77	64.35	76.81	65.31
12	90	160	....	63.15	25.72	76.34	66.59	63.34	71.97	65.46
Average	....	....	....	62.45	24.84	70.47	66.18	63.84	74.39	65.88
11	66	100	600	63.79	25.17	71.05	64.25	69.19	70.18	68.48
12	90	100	600	64.70	28.76	74.21	62.22	68.69	84.45	69.07
1	42	100	600	58.46	26.15	63.00	60.49	63.62	64.15	62.87
Average	....	....	....	62.32	26.69	69.42	62.32	67.17	72.93	66.81
11	66	50	1,050	61.08	31.71	89.72	52.86	63.55	75.02	65.72
2	54	45	1,080	60.17	39.14	84.28	53.47	61.74	67.99	63.73
1	42	50	1,200	59.79	32.68	84.54	56.45	63.33	62.99	64.18
Average	....	....	....	60.35	34.51	86.18	54.26	62.87	68.67	64.54
1	....	....	1,170	58.20	36.87	75.29	38.09	66.93	76.93	63.84
3	....	....	1,200	64.96	39.88	67.83	47.88	76.17	54.83	70.59
Average	....	....	....	61.58	38.37	71.56	42.98	71.55	65.88	67.21

METHOD OF CALCULATING DIGESTIBLE NUTRIENTS

Table X gives the estimated coefficients of digestion for each class of rations fed during the digestion trials, the actual coefficients of digestion as determined by these trials, and the factor showing the difference between the estimated and the actual coefficients. In arriving at the estimated coefficients the average figures for sorghum fodder, corn, wheat bran, and cottonseed meal were taken from Henry (8, p. 572–577), while the figures for prickly-pear were taken from our own results as given in Table IX. In determining the digestible nutrients consumed by the different groups of cows in this feeding experiment the crude nutrients consumed were multiplied by the average coefficients of digestion as taken from Henry and the resulting products multiplied by the factor of difference for that particular group. This method is given with a full knowledge of the error involved in assuming that the coefficients of digestion for the different constituents are increased or decreased in the same ratio for each ingredient of the ration. As a matter of fact, it is probable that in some rations the digestibility of one ingredient may be reduced while that of another may be increased. However, calculations using average coefficients and the factors of difference are thought to be more nearly repre-

sentative of actual conditions than calculations involving only the use of the average coefficients.

TABLE X.—*Comparison of estimated and actual coefficients of digestion for dairy cattle*

HAY GROUP

Coefficient of digestion.	Nos. of cows.	Dry matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Estimated	11, 12	64.56	68.20	48.19	68.46	78.46
Actual	11, 12	62.45	70.47	66.18	63.84	74.21
Factor of difference		.97	1.03	1.37	.93	.95

MEDIUM PRICKLY-PEAR GROUP

Coefficient of digestion.	Nos. of cows.	Dry matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Estimated	1, 11, 12	64.84	70.91	46.99	70.64	77.82
Actual	1, 11, 12	62.32	69.42	62.32	67.17	72.93
Factor of difference		.96	.98	1.33	.95	.94

HEAVY PRICKLY-PEAR GROUP

Coefficient of digestion.	Nos. of cows.	Dry matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Estimated	1, 2, 11	64.01	73.08	45.55	72.03	75.68
Actual	1, 2, 11	60.35	86.18	54.26	62.87	68.67
Factor of difference		.94	1.18	1.19	.87	.90

INFLUENCE OF PRICKLY-PEAR ON DIGESTIBILITY OF OTHER FEEDS

It has been claimed that prickly-pear is more valuable than its analysis indicates, for the reason that it increases the digestibility of any material with which it may be fed. To determine the accuracy of this statement Table XI was prepared by applying average coefficients of digestion to the nutrients fed in the digestion trials as determined from the weight and analyses of the feeds. These were then compared with the actual coefficients.

TABLE XI.—*Comparison of estimated and actual coefficients of digestion for dairy cows*

COMPARISON OF HAY, GRAIN, AND MEDIUM RATIONS OF PRICKLY-PEAR

Coefficient of digestion.	Nos. of cows.	Dry matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Organic matter.
Hay and grain:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Estimated	11, 12	64.56	68.20	48.19	68.46	78.49	63.80
Actual	11, 12	62.45	70.47	66.18	63.84	74.21	65.88
Difference							+2.08
Medium prickly-pear, hay, and grain:							
Estimated	11, 12	65.70	72.47	46.76	71.39	79.17	66.92
Actual	11, 12	64.24	72.63	63.23	68.94	77.31	68.77
Difference							+1.85

TABLE XI.—*Comparison of estimated and actual coefficients of digestion for dairy cows*—Continued

COMPARISON OF HAY, GRAIN, AND MEDIUM AND HEAVY RATIONS OF PRICKLY-PEAR

Cofficient of digestion.	Nos. of cows.	Dry matter.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Organic matter.
Medium prickly-pear, hay, and grain:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Estimated	11, 1	64.01	69.48	47.16	69.86	76.88	65.12
Actual	11, 1	61.12	67.02	61.37	66.40	67.16	65.67
Difference							+0.55
Heavy prickly-pear, hay, and grain:							
Estimated	11, 1	63.54	72.90	45.55	71.94	76.73	65.57
Actual	11, 1	60.43	87.13	54.65	63.44	69.00	64.95
Difference							−2.62
Prickly-pear alone:							
Actual	1, 3	61.58	71.56	42.98	71.55	65.88	67.21

It will be observed from this table that when hay and grain were fed the actual coefficient for organic matter exceeded the estimated by 2.08 per cent, and that when hay, grain, and a moderate quantity of prickly-pear (60 pounds per day) were fed the actual exceeded the estimated by 1.85 per cent. These results indicate that prickly-pear in moderate amounts has little effect on the digestibility of the other organic ingredients of the ration. The effect of a large ration of prickly-pear (105 to 120 pounds) as compared with a medium ration will be seen from the results with cows 11 and 1. When fed the medium ration, the actual exceeded the estimated coefficient by 0.55 per cent; when fed the large ration, the actual was 2.62 per cent less than the estimate. These figures indicate that a large amount of prickly-pear in the ration depressed the coefficient of digestion.

The results of the writers' digestion trials with prickly-pear as the sole feed agree fairly well with those obtained by Hare (7). The trials reported in this paper show a less efficient digestion of dry matter, fiber, nitrogen-free extract, ether extract, and organic matter, but a more efficient digestion of ash and especially of protein. In general, the coefficients of digestion secured by Hare are greater than those obtained in the trials of the writers (Table XII).

TABLE XII.—*Comparison of digestion coefficients of prickly-pear with those of previous trials*

Ration entirely of prickly-pear.	Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Organic matter.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent*	*Per cent.*	*Per cent*	*Per cent*
Average of our trials (see Table IX)	61.58	38.37	71.56	42.98	71.55	65.88	67.21
Average of Hare's trials	64.91	35.69	49.56	47.66	80.77	68.46	72.76
Difference	−3.33	+2.68	+22.00	−4.68	−9.22	−2.58	−5.55

INFLUENCE OF PRICKLY-PEAR ON PERCENTAGE OF FAT IN MILK

It is a common belief of many farmers that the percentage of fat in milk varies according to the character of the ration; on the other hand, the results from several experiment stations indicate that the fat content is an individual characteristic that is not affected by the feed. The average percentage of fat in the milk for each cow during the entire feeding periods is given in Table XIII and shows conclusively that prickly-pear in the ration caused a reduction in the percentage of fat.

TABLE XIII.—*Influence of prickly-pear on percentage of fat in milk. Averages for the various feeds during full periods of 80 days*

No. of cow.	80-day period.	Feed.	Fat.	80-day period.	Feed.	Fat.
			Per cent.			*Per ct.*
1	First	Heavy prickly-pear	3.88	Second	Medium prickly-pear	3.87
2	do	do	3.83	do	do	4.09
3	do	do	3.98	do	do	4.34
4	Second	do	4.35	First	do	4.92
5	do	do	3.76	do	do	4.15
6	do	do	3.86	do	do	4.32
Average			3.94			4.28
8	First	Medium prickly-pear	3.91	Second	Sorghum hay	4.11
9	do	do	3.68	do	do	3.97
10	Second	do	3.78	First	do	4.24
11	do	do	3.77	do	do	4.52
12	do	do	5.37	do	do	5.88
Average			4.10			4.54
4	Second	Medium prickly-pear	4.75	First	Cottonseed hulls	5.18
5	do	do	4.42	do	do	5.03
10	do	do	4.11	do	do	4.44
8	First	do	3.95	Second	do	4.23
11	do	do	4.17	do	do	4.46
12	do	do	5.72	do	do	6.19
Average			4.52			4.92
3	Second	Medium prickly-pear	4.12	First	Sorghum silage	4.49
14	do	do	4.74	do	do	5.00
17	do	do	4.79	do	do	5.13
19	do	do	5.26	do	do	5.60
20	do	do	4.92	do	do	5.51
6	First	do	4.39	Second	do	5.02
9	do	do	3.96	do	do	4.08
15	do	do	4.12	do	do	4.42
16	do	do	4.03	do	do	4.46
18	do	do	5.16	do	do	6.01
Average			4.55			4.97

In order to ascertain the more immediate effect on the fat percentage of feeding prickly-pear, Table XIV has been prepared, showing a comparison between the last 10-day period preceding the change in the ration and the first 10-day period after the change. As stated before, 10 days were allowed between the periods for making the change.

TABLE XIV.—*Influence of prickly-pear on percentage of fat in milk. Averages for the various feeds for 10 days before and 10 days after the change of ration*

No. of cow.	10-day period.	Feed.	Fat.	10-day period.	Feed.	Fat.
			Per ct.			*Per ct.*
1	Before change.	Heavy prickly-pear.	3.70	After change..	Medium prickly-pear.	3.80
2	.....do	.....do	3.75	.....do	.....do	3.90
3	.....do	.....do	3.85	.....do	.....do	4.05
4	After change..	.....do	4.30	Before change.	.....do	4.60
5	.....do	.....do	3.75	.....do	.....do	4.15
6	.....do	.....do	3.85	.....do	.....do	4.00
Average...			3.87			4.08
8	Before change.	Medium prickly-pear.	3.90	After change..	Sorghum hay.....	4.60
9	.....do	.....do	3.50	.....do	.....do	3.90
10	After change..	.....do	5.70	Before change.	.....do	4.20
11	.....do	.....do	3.85	.....do	.....do	4.40
12	.....do	.....do	5.55	.....do	.....do	6.20
Average...			4.10			4.66
4	After change..	Medium prickly-pear.	4.80	Before change.	Cottonseed hulls..	5.10
5	.....do	.....do	4.20	.....do	.....do	5.20
10	.....do	.....do	4.40	.....do	.....do	4.25
8	Before change.	.....do	3.75	After change..	.....do	3.95
11	.....do	.....do	4.00	.....do	.....do	4.45
12	.....do	.....do	5.60	.....do	.....do	6.00
Average...			4.46			4.82
3	After change..	Medium prickly-pear.	4.35	Before change.	Sorghum silage....	4.75
14	.....do	.....do	4.80	.....do	.....do	5.30
17	.....do	.....do	5.00	.....do	.....do	5.55
19	.....do	.....do	5.35	.....do	.....do	5.80
20	.....do	.....do	5.20	.....do	.....do	5.80
6	Before change.	.....do	4.30	After change..	.....do	4.90
9	.....do	.....do	3.80	.....do	.....do	4.00
15	.....do	.....do	4.15	.....do	.....do	4.35
16	.....do	.....do	4.00	.....do	.....do	4.40
18	.....do	.....do	5.25	.....do	.....do	5.70
Average...			4.62			5.05

INFLUENCE OF PRICKLY-PEAR ON FLAVOR OF MILK AND QUALITY OF BUTTER

The milk from the experimental cows was tested for flavor almost daily throughout the feeding trials, and at no time was there any objectionable flavor detected. Some dairymen in southern Texas believe that prickly-pear injures the keeping quality of milk. In order to ascertain whether there was any basis for this belief, samples were on three different occasions taken from cows that were receiving prickly-pear and from cows that were fed hay as the only roughage. These samples were placed in clean bottles and kept at ordinary atmospheric temperature. No difference was observed in the time required for souring, and no objectionable flavor was manifest at any time. It is probable that under ordinary farm conditions milk from cows fed on prickly-pear does not keep so well as milk from cows fed on hay, because milk from the former is more liable to become contaminated with acid-producing bacteria, owing to the laxative character of prickly-pear and the consequent insanitary condition of the cow and stable.

Two tests were made to ascertain the effect of prickly-pear upon the quality of butter. No expert judges were available for scoring the butter, but the tests indicate that prickly-pear exerts little, if any, unfavorable influence on the flavor. Some difficulty was experienced in churning the cream of the cow fed on cottonseed meal, with prickly-pear as the sole roughage. Before butter could be made from this lot of cream it was necessary to raise it to a temperature of 65° F., five degrees higher than the churning temperature of the other lots of cream. Both the difficult churning of the cream and the hardness of this lot of butter seemed to be due to the cottonseed meal. The only noticeable effect of prickly-pear was the higher color of the butter (Table XV).

TABLE XV.—*The influence of prickly-pear upon the quality of butter*

No. of cow.	Feed.	Temperature of cream.	Length of churning period.	Color of butter.	Flavor of butter.	Hardness of butter.
		° *F.*	*Minutes.*			
12	Mixed grain, hay	58	10	White	Good	Medium.
13	Cottonseed meal, prickly-pear	65	20	Yellow	Good	Hard.
5	Mixed grain, hay, prickly-pear	60	14	Yellow	Good	Medium.
8	Grain, hay	60	12	White	Good	Medium.

EFFECT OF FEEDING PRICKLY-PEAR ALONE AS ROUGHAGE

Cow 13 was placed on a daily ration of about 4 pounds of cottonseed meal and as much prickly-pear as she would eat. This ration was continued for 371 days. During this time she consumed a total of 1,428 pounds of cottonseed meal, an average of 3.85 pounds a day, and 41,730 pounds of prickly-pear, an average of 112.5 pounds a day. At the beginning of this period the cow weighed 737 pounds, at the close 696 pounds, a loss of 41 pounds. During this time she produced 1,045 pounds of milk, containing 54.5 pounds of fat, and gave birth to a calf. Soon after being placed on this ration containing only prickly-pear as roughage her coat became rough, she scoured badly, and gave other evidence that she was not properly nourished. After 371 days of feeding on prickly-pear and cottonseed meal, the latter was withdrawn from the ration and prickly-pear alone was continued for 80 days. During this period she consumed a total of 9,919 pounds of prickly-pear, an average of 124 pounds a day, and produced but 24 pounds of milk and 1.1 pounds of fat, as her milk production was very low and she was dried up within 10 days after the beginning of the period. During this 80-day period she lost 24 pounds in weight. A ration of mixed grain, sorghum hay, and prickly-pear was then given to her. Within a week she stopped scouring and improved rapidly in appearance and condition. Apparently there were no permanent ill effects from her extended ration of prickly-pear.

Cow 1 was fed an average daily ration of 5 pounds of cottonseed meal and 141.7 pounds of prickly-pear for a period of 170 days. This cow

weighed 850 pounds at the beginning and 851 pounds at the close. She produced 2,204.8 pounds of milk and 87.76 pounds of fat. During the preceding year, under similar conditions except for feed, she produced in the same length of time 1,522.4 pounds of milk and 58.98 pounds of fat. Her feed during the first year consisted of mixed grain, hay, and prickly-pear. Owing to better physical condition at time of parturition, all the cows used for the first year's work gave an increase of both milk and butter fat during the second year's work. However, the percentage of increase of cow 1 was double that of the average of the remaining cows. This cow remained in good condition all the time and appeared to be as well nourished as the preceding year. Like cow 13, she scoured badly, but ceased to do so when the character of the ration was changed.

It is evident that there is a great difference in individual cows in their ability to subsist upon a ration containing prickly-pear as the sole roughage. Cow 1 always ate prickly-pear with great relish; cow 13 always ate it reluctantly. In fact, these two cows perhaps represented the two extremes as regards their appetite for prickly-pear. It is evident that the matter of palatability is an important consideration in determining whether or not to feed a ration containing prickly-pear as the sole roughage.

Summing up the results obtained with these two cows, it was found that both scoured badly but that neither was permanently injured in any way. One of them thrived, while the other did not. The explanation offered for this is the difference in the individuality of the two cows.

It may not be wise, however, to feed any cows exclusively on prickly-pear, as it may cause an obstruction of the intestine and the death of the animal. Cow 2, which was fed 120 pounds of prickly-pear each day, became ill following the experimental work, and after seven days of feeding on prickly-pear alone refused to eat feed of any kind. Prior to being fed on prickly-pear alone this cow was on a ration of 120 pounds of prickly-pear, 5 pounds of sorghum hay, and 6 pounds of mixed grain a day for a period of 15 days. Her illness was diagnosed as an obstruction of the intestine, and every effort was made to remove it. When a post-mortem examination was made, a tightly compressed mass of fiber about the size of a goose egg was found at the beginning of the small intestine. In addition, there was a large amount of undigested fiber closely matted together in the fourth stomach. No other animals suffered from any trouble of this sort, although three other cows were fed a ration of prickly-pear only, and at different times during these experiments seven were fed a heavy prickly-pear ration.

INFLUENCE OF THE MINERAL MATTER CONTAINED IN PRICKLY-PEAR

Prickly-pear contains a large amount of mineral matter, which no doubt is responsible in part for the well-known laxative nature of the plant. While in ordinary feed practice this high content of mineral matter is perhaps of no advantage, it may be desirable if the remainder

of the ration is deficient in mineral matter. Cows producing large quantities of milk require considerable mineral matter, especially calcium; and as some feeds, like cottonseed hulls, are low in mineral elements, it is thought that prickly-pear is a valuable supplement to such feeds. Cow 5, a strong, vigorous, high-producing animal, when fed a ration with cottonseed hulls as the sole roughage, became so ill in about 10 weeks that it was necessary to change her ration. She showed an abnormal appetite for common salt (sodium chlorid) and upon moving about groaned as if in pain. The treatment ordinarily administered for cases of indigestion afforded no relief, but upon the addition of prickly-pear to her ration she recovered promptly. Cows producing smaller quantities of milk and possessing less robust constitutions, although fed in the same way, remained unaffected. These facts suggest that this cow suffered from a deficiency of mineral elements in her ration.

EFFECT OF FEEDING PRICKLY-PEAR UPON THE OFFSPRING OF DAIRY COWS

In order to determine the effect of prickly-pear upon the offspring, the herd was divided into four groups as soon as the feeding experiment was finished. The first group was fed sorghum hay alone as a roughage; the second, sorghum hay with a medium amount of prickly-pear; the third, sorghum hay with a large quantity of prickly-pear; and the fourth, prickly-pear alone. Grain was fed in such amounts as were necessary to put the cows in good condition at the time of calving. The grain ration of the cows receiving prickly-pear alone as roughage consisted entirely of cottonseed meal; the cows in the other groups received the same grain mixture that was used in the feeding experiment. Except for a period of two or three weeks, when some of the animals were on digestion trials, these rations were continued until the cows freshened, making a period of about five months for each cow.

Table XVI gives the numbers of the cows in each group, the character of their rations, the length of the gestation period, weight of the dam, the sex and weight of the calf, and some brief notes on the condition of the calf at birth.

TABLE XVI.—*Effect of feeding prickly-pear upon the offspring of dairy cows*

No. of cow.	Roughage ration.	Length of gestation period.	Weight of dam.	Sex of calf.	Birth weight of calf.	Condition of calf.
		Days.	*Pounds.*		*Pounds.*	
1	Prickly-pear alone	274	912	Male	59	Fair.
13	do	279	696	Female	48	Weak, died of white scours.
3	Heavy prickly-pear	272	870	Male Female	48 39	Twin calves, both small but vigorous.
5	do	276	907	Female	60	Fair.
4	Medium prickly-pear	281	920	do	57	Big-boned, weak.
6	do	273	890	do	57	Strong.
10	do	279	700	do	59	Do.
11	do	277	762	do	58	Do.
8	No prickly-pear	273	809	Male	56	Fair.
9	do	272	800	Female	58	Small-boned, vigorous.
12	do	274	806	Male	45	Small, weak, grew well.

All the cows, except No. 13, were in good condition at the time of calving, and their general health returned to normal within a short time. A small part of the afterbirth was retained for 48 hours by cow 3.

It may be noted that all the calves were rather light in weight as compared with their dams at the time of parturition, but only a few were lacking in vigor. The calves were taken from their dams within 24 hours after birth, and all received the same feed and care. With the exception of the calf from cow 13, they grew normally and no trouble was experienced from scours or from any other calf diseases. Cow 13 calved about three weeks later than any of the others. She was in poor condition at the time, as she had been getting a ration with prickly-pear as the sole roughage. Her calf developed white scours and died within a short time.

The data obtained are too meager to admit of positive conclusions, but it appears that prickly-pear has no great influence on the size and vigor of the offspring, at least when supplemented with some dry roughage.

EFFECT OF COMMON SALT ON THE LAXATIVE PROPERTY OF PRICKLY-PEAR

Some feeders of prickly-pear in southern Texas make a practice of adding common salt to the ration, with the object of lessening its laxative property. The fact that prickly-pear contains a relatively small quantity of sodium made it appear possible that there is some basis for this belief. In order to test this matter, one cow was fed a daily ration of 150 pounds of prickly-pear, 4 pounds of sorghum hay, and 4 pounds of a grain mixture of corn meal, wheat bran, and cottonseed meal; another cow was fed a ration of 150 pounds of prickly-pear and 4 pounds of cottonseed meal.

Sodium chlorid was scattered over the chopped prickly-pear, using ½ ounce to each cow on the first day and increasing the quantity at the rate of ½ ounce a day until the cows refused to eat the feed. One of the cows refused to eat prickly-pear when 4½ ounces of common salt a day were added to it; the other refused her feed when 6½ ounces had been scattered over the ration; but both animals readily ate unsalted prickly-pear whenever it was offered. Both cows were fed for four days on prickly-pear salted to the maximum amount for each animal. No apparent change in the character of the feces was noticeable as the result of feeding the salted ration. Until the maximum quantity of common salt was reached, both cows seemed to have a better appetite for prickly-pear, and they drank a small quantity of water each morning, which they did not always do when common salt was not fed. This test was repeated, using the same cows and feeding them in the same manner as before, with similar results. The two tests indicate that the addition of sodium chlorid to a ration of prickly-pear will have no appreciable effect on the laxative properties of the plant.

EFFECT OF FEEDING PRICKLY-PEAR ON THE QUANTITY OF WATER DRUNK BY DAIRY COWS

Prickly-pear grows readily in semiarid regions, where the water supply for cattle is often a serious problem. It has such a high water content that it was thought to be of interest to ascertain the quantity of water drunk by animals fed with prickly-pear. In November, 1911, a short test was conducted for this purpose; the amount of water drunk by the different animals was recorded for a period of three days, the cows being watered twice daily. Later, in May and June, 1912, while conducting some digestion trials, the quantities of water drunk by the animals used in these trials were also weighed. The results are given in Table XVII.

TABLE XVII.—*Effect of feeding prickly-pear upon the amount of water drunk by dairy cows*

Date.	Length of period.	Number of cows.	Feed.	Average daily amount of water drunk by each cow.
	Days.			*Pounds.*
November, 1911	3	3	Heavy prickly-pear	5
Do	3	3	Medium prickly-pear	30
Do	3	3	Sorghum hay	69
Do	3	1	Prickly-pear alone	0
May, 1912	10	2	Sorghum hay	95
May and June, 1912	10	4	Medium prickly-pear	44.3
June, 1912	10	2	Heavy prickly-pear	0
May and June, 1912	10	2	Prickly-pear alone	0.3

The warmer weather at the time the digestion trials were made caused an increased consumption of water by the hay-fed cows, but not by those heavily fed with prickly-pear. The results of these two trials indicate that prickly-pear may be of special value in case of shortage of water. It is possible that animals fed a heavy or an entire roughage ration of prickly-pear can subsist for a considerable time without water. During the 3-day trial the cow getting a roughage ration entirely of prickly-pear drank no water, and the heavy-ration prickly-pear group drank but a small quantity. During the longer period the cows on entire prickly-pear and heavy prickly-pear rations drank very little water, although it was freely offered to them.

EFFECT OF NORTHERS ON COWS FED WITH PRICKLY-PEAR

Southern Texas, where this experiment was conducted, is subject during the winter months to sudden and decided drops in temperature, accompanied by strong north winds, locally called "northers." During the early part of the winter it was noticed that the cows receiving the heavier prickly-pear ration were apparently more sensitive to these

sudden changes of temperature. The effect of feeding the different rations during severe weather will be readily noted in Table XVIII and also graphically in figure 1. It will be seen that the cows fed heavy rations of prickly-pear showed an average decrease of 7.50 per cent in their milk production on the days of the northers, the cows fed medium rations a decrease of 4.03 per cent, while the milk flow of cows that received no prickly-pear in their ration decreased but 1.92 per cent. These data indicate that the cows feeding on prickly-pear were more sensitive to cold weather than those receiving hay and that the larger quantity of the plant caused the greater sensitiveness. That the greater decrease in production of the prickly-pear-fed cows is due entirely to the change in temperature is more apparent when it is noted that all the cows returned to practically the same percentage of their normal production on the second day following the northers.

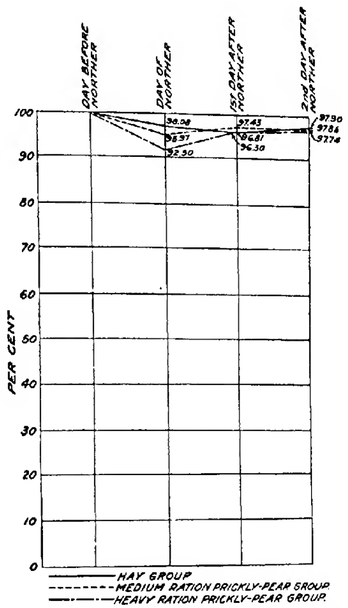

Fig. 1.—Effect of northers upon yield of milk by cows fed with different rations.

Table XVIII.—*Effect of 13 northers upon the milk yield of cows fed with prickly-pear and hay*

Group.	Average total milk yield per group.				Percentage of decrease from day before norther.		
	Day before norther.	Day of norther.	First day after norther.	Second day after norther.	Day of norther.	First day after norther.	Second day after norther.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Per cent.*
Heavy prickly-pear	207.9	192.3	200.2	203.2	7.50	3.70	2.26
Medium prickly-pear	260.3	249.8	253.6	254.7	4.03	2.57	2.15
Sorghum hay	229.1	224.7	221.8	224.3	1.92	3.19	2.10

USE OF PRICKLY-PEAR FOR MAINTENANCE OF DRY COWS

At the close of the first year's work a number of maintenance trials with dry cows were conducted, using the several roughage rations fed during the first year's work. In all these trials cottonseed meal was the only grain fed. A summary of the results is given in Table XIX.

TABLE XIX.—*Results of tests showing the value of prickly-pear as a maintenance ration for dry dairy cows*

No. of cow.	Length of period.	Initial weight.	Final weight.	Average daily amount of feed consumed by each cow.		
				Grain.	Sorghum hay.	Prickly-pear.
	Days.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
3	50	867.4	867.0	1	3.5	105
6	70	796.8	795.6	1	4.0	60
4	50	884.6	885.8	1	6.2	60
13	60	754.8	754.4	2	0	105
1	50	891.6	891.2	2	0	113
13	70	702.0	671.8	0	0	126

In conducting the trials in which both prickly-pear and sorghum hay were fed, the cacti as well as the grain were supplied in fixed quantities, and the sorghum hay was fed in addition in such amounts as to control the body weights. In those trials where prickly-pear was the sole roughage, 120 pounds of prickly-pear a day were fed at the beginning; but later it was found necessary to reduce this quantity to control the body weights. The results of these trials show that mature Jersey cows can be maintained on a ration of 3.5 to 6 pounds of sorghum hay and 60 to 105 pounds of prickly-pear, with 1 pound of cottonseed meal a day. If prickly-pear is used as the sole roughage, it will require about 110 pounds of that plant with an increase of cottonseed meal to 2 a day.

In order to ascertain the possibility of using prickly-pear without supplementary feed as a maintenance ration a second trial was conducted with cow 13. Prickly-pear was fed to this cow in as large quantities as she would consume, the feeding being continued in this manner for 70 days. This cow was in poor condition at the beginning of the 70-day period, and during the period she lost 30.2 pounds. It appears from this trial that prickly-pear alone is not a satisfactory maintenance ration, but that it will keep an animal alive for a considerable time where there is a shortage of or total absence of other feed.

METHOD AND COST OF HARVESTING PRICKLY-PEAR

The cost of harvesting prickly-pear can be only approximately determined, as so much depends upon local conditions. Before the spiny varieties of prickly-pear can be fed they must be treated in such manner as either to remove or soften the spines. The most common method of

removing them is by means of singeing with a strong gasoline torch, as shown in Plate LXI, figure 1, or by burning the spines off over a brush fire, if but a small quantity of prickly-pear is to be fed. Chopping machines have been used with some success to render the spines practically harmless, but the practice of singeing with the gasoline torch is economical in both labor and the greater utility of the prepared feed (4, p. 13). By using the gasoline torch in an average of three trials at Brownsville, Tex., by the Bureau of Animal Industry, it was found that 50 minutes' time and 1⅔ gallons of gasoline were required to singe 1 ton of the spiny prickly-pear. These trials were conducted with a 2-year growth of the plant that yielded at the rate of about 80 tons an acre per annum. With the class of labor obtainable and the price of gasoline at that time, it was estimated that prickly-pear could be singed at a cost of approximately 50 cents a ton.

There are two methods of feeding prickly-pear from which the spines have been removed: The cattle may graze the standing plant down to the heavier stems or it may be cut down and hauled to the feed lots. The first method requires less labor, but is more wasteful and is not advisable, especially with a cultivated plantation, unless the supply of prickly-pear is plentiful. If the cacti are removed to feed lots, the cost of feeding will depend upon the proximity of the lots and the accommodations for feeding. One man with a team can haul and feed from 3 to 6 tons a day (Pl. LXI, fig. 2, and LXII, fig. 1).

A test on a small scale showed that prickly-pear was not suitable for making silage. At the end of 30 days only the small spines had been softened; furthermore, the cows would not eat it.

COMPARATIVE VALUE OF SPINY AND SPINELESS PRICKLY-PEAR

The spineless varieties of prickly-pear are relatively free from thorns or spines. They have practically the same chemical composition as the spiny varieties and are probably of equal value for feeding purposes. However, they are less hardy than the spiny varieties and more subject to injury from low temperatures, so that the area in which they can be successfully grown is much more restricted than that of the spiny varieties. But little accurate information is obtainable as to the yield of the spineless varieties. In work conducted at Chico, Cal., by one of the writers (6, p. 9) an annual yield of from 20 to 25 tons an acre was obtained. These yields were obtained with expert cultivation and by maintaining a perfect stand. At Brownsville, Tex., where the work reported in this paper was conducted, there is no authentic record of the yield of the spineless varieties. It is known, however, that because of insects and low temperature the yield is much less than that of the native spiny forms.

The spineless and the spiny varieties are apparently of equal value for milk production. During the latter part of the second year's work the spineless prickly-pear was substituted for the spiny in the ration of all

the cows fed with this plant. There is apparently some difference in taste between the raw spineless and the singed spiny prickly-pear, as some of the cows ate the former with somewhat less relish for the first few days after the change was made. This was likewise true when the spiny prickly-pear was again fed, but in both cases the two varieties were eaten with equal relish after the first few days of feeding. No change in production or body condition was caused by the change in the kind of prickly-pear fed, and the spineless had the same laxative effect as the spiny variety.

The cost of harvesting and feeding the spineless kind would differ from that of the spiny varieties only in the cost of singeing. The spineless prickly-pear, unlike the spiny form, could not be harvested by grazing, for the amount to be fed daily could not be controlled, as is the case with the spiny forms. The waste of feed and destruction of plants by stock in the field would be so great as to make that method of harvesting less economical than cutting and hauling the cacti to a feed lot.

SUMMARY

The average analysis of prickly-pear fed in these experiments was as follows: Water, 91.30 per cent; crude protein (N × 6.25), 0.58 per cent; albuminoid protein, 0.29 per cent; ether extract, 0.12 per cent; nitrogen-free extract, 4.67 per cent; crude fiber, 1.16 per cent; ash, 1.76 per cent.

Prickly-pear was found to be a very palatable feed for dairy cows, even when it formed the major part of the roughage ration, and 100 to 150 pounds were consumed per cow per day.

The prickly-pear ration caused an increase in the quantity of milk produced, a decrease in the percentage of fat in the milk, and a decrease in the total production of fat. The reduction in the percentage of fat became more pronounced as the quantity of prickly-pears in the ration increased.

Assuming the feeds to have these percentages of dry matter—prickly-pear, 10; sorghum hay, 80; sorghum silage, 25; and cottonseed hulls, 90—and considering the nutritive values to vary in direct proportion to the content of dry matter, 1 pound of sorghum hay was equal to 15.9 pounds of prickly-pear when that plant was fed in large quantities and to 10.1 pounds of prickly-pear when it was fed in moderate amounts. One pound of sorghum silage was equal to 2.6 pounds of prickly-pear, and 1 pound of cottonseed hulls was equal to 5.8 pounds of prickly-pear.

When prickly-pear in moderate amounts was substituted for a part of the dry roughage, it appeared to have little effect on the digestion of the other ingredients of the ration; when substituted in large amounts it depressed the coefficient of digestion, although not to any great extent.

As the result of maintenance trials conducted during these experiments, it is believed that mature Jersey cows can be maintained on a daily

ration of 3.5 to 6 pounds of sorghum hay, 60 to 100 pounds of prickly-pear, and 1 pound of cottonseed meal a day; or, with prickly-pear as the sole roughage, about 110 pounds of that plant and 2 pounds of cottonseed meal. Prickly-pear alone did not make a satisfactory maintenance ration, but sustained life for a long time. One cow that was fed prickly-pear alone for a period of 70 days lost 30.2 pounds live weight.

The average coefficients of digestion in two trials with prickly-pear as the sole ration were as follows: Dry matter, 61.58; ash, 38.37; crude protein, 71.56; crude fiber, 42.98; nitrogen-free extract, 71.55; ether extract, 65.88; organic matter, 67.21.

Palatability was apparently an important factor in feeding prickly-pears as the sole roughage. One cow that ate prickly-pear with relish did as well on the ration when that plant was the sole roughage as when some dry roughage was included. Another that ate prickly-pear reluctantly lost in weight. In one case feeding prickly-pear alone caused the formation of an obstruction in the intestine and the death of the animal.

The feeding of prickly-pear produced a highly colored butter, but had no appreciable effect upon the flavor or keeping quality of the milk.

Prickly-pear had a decidedly laxative effect on the cows, although there seemed to be no permanent ill effects even after long-continued feeding. The addition of common salt (sodium chlorid) to a ration of prickly-pear even when added in large amounts, 4 to 6 ounces a day to each cow, had no appreciable effect upon the laxative property of the plant.

During an experimental period of 10 days cows receiving a heavy ration of prickly-pear drank no water, those receiving a medium ration drank an average of 44.3 pounds of water per day, while those on a roughage ration of sorghum hay drank a daily average of 95 pounds.

As measured by milk production cows fed prickly-pear were more sensitive to northers than those which received a dry roughage. The greater the quantity of the plant consumed the more sensitive the animal became.

The prickly-pear ration appeared to have no great influence upon the size and vigor of the offspring or upon the condition of the cow after parturition.

The cost of harvesting prickly-pear depends largely upon local conditions. During these experiments it was found that the spines could be singed at a cost of about 50 cents per ton.

There was no great difference between the spineless and the spiny varieties of prickly-pear in composition, palatability, or feeding value. While the cost of harvesting the spineless was less than that of the spiny varieties, the latter yielded a greater tonnage to the acre at Brownsville, Tex., and were not so subject to injury from insects. The spiny varieties are hardier and can be grown in a much greater area than the spineless.

These experiments were conducted for periods long enough to show conclusively that prickly-pear is a good and palatable feed for dairy cows. It is best to feed the plant in medium quantities, 60 to 75 pounds a day to each cow. When fed in large amounts, 120 to 150 pounds a day, it causes an excessive scouring and a very insanitary condition of the stable. On account of the high content of mineral matter, it is thought that prickly-pear may be of special value as a supplementary feed for use with other roughages of a low mineral-matter content, such as cottonseed hulls.

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TABLE XX.—*Milk production (first year): Prickly-pear versus sorghum hay*

FIRST PERIOD (80 DAYS)

No. of cow.	Group.	Total milk.	Fat in milk. Average per cent.	Fat in milk. Total amount.	Average specific gravity.	Total solids.
		Pounds.	*Per cent.*	*Pounds.*		*Pounds.*
1	Heavy prickly-pear	806.7	3.88	31.34	1.0327	103.62
2	do	1,426.4	3.83	54.57	1.0322	180.52
3	do	1,482.9	3.98	58.96	1.0326	191.83
Total		3,716.0	3.90	144.87	....	475.97
4	Medium prickly-pear	1,332.0	4.92	65.49	1.0327	187.77
5	do	2,093.6	4.15	86.97	1.0324	274.14
6	do	1,251.0	4.32	54.07	1.0332	168.91
Total		4,676.6	4.42	206.53	....	630.82
8	Medium prickly-pear	2,055.1	3.91	80.27	1.0312	256.80
9	do	1,488.0	3.68	54.83	1.0328	188.01
Total		3,543.1	3.81	135.10	....	444.81
10	Sorghum hay	1,394.4	4.24	59.06	1.0329	185.95
11	do	1,734.4	4.52	78.34	1.0325	235.30
12	do	1,482.5	5.88	87.15	1.0347	233.62
Total		4,611.3	4.87	224.55	....	654.87
13	Prickly-pear alone	575.6	5.06	29.11	1.0322	81.37

SECOND PERIOD (80 DAYS)

No. of cow.	Group.	Total milk.	Fat in milk. Average per cent.	Fat in milk. Total amount.	Average specific gravity.	Total solids.
1	Medium prickly-pear	637.6	3.87	24.67	1.0314	79.69
2	do	1,288.4	4.09	52.65	1.0317	165.38
3	do	1,280.8	4.34	55.59	1.0325	170.99
Total		3,206.8	4.14	132.91	....	416.06
4	Heavy prickly-pear	1,132.1	4.35	49.25	1.0371	150.12
5	do	2,248.2	3.76	84.54	1.0321	282.16
6	do	1,062.0	3.86	40.97	1.0327	136.13
Total		4,442.3	3.93	174.76	....	568.41
8	Sorghum hay	1,757.9	4.11	72.25	1.0303	220.09
9	do	1,472.9	3.97	58.44	1.0324	189.53
Total		3,230.8	4.04	130.69	....	409.62
10	Medium prickly-pear	1,230.9	3.78	46.49	1.0325	155.92
11	do	1,622.9	3.77	61.24	1.0319	203.08
12	do	1,532.0	5.37	82.25	1.0341	229.78
Total		4,385.8	4.33	189.98	....	588.78
13	Prickly-pear alone	392.0	5.47	21.44	1.0312	56.37

TABLE XXI.—*Milk production (second year): Prickly-pear versus sorghum silage*

FIRST PERIOD (80 DAYS)

No. of cow.	Group.	Total milk.	Fat in milk.		Average specific gravity.	Total solids.
			Average percentage.	Total amount.		
		Pounds.	*Per cent.*	*Pounds.*		*Pounds.*
3	Sorghum silage	1,660.0	4.49	74.84	1.0321	223.24
14	do	1,183.5	5.00	59.26	1.0332	169.50
17	do	1,889.3	5.13	97.05	1.0335	275.02
19	do	1,795.6	5.60	100.57	1.0339	273.51
20	do	1,110.1	5.51	61.14	1.0321	162.69
Total		7,638.5	5.14	392.86		1,103.93
6	Prickly-pear	1,640.4	4.39	72.11	1.0331	222.21
9	do	2,364.5	3.96	93.70	1.0311	295.80
15	do	1,457.1	4.12	60.04	1.0316	156.35
16	do	1,830.1	4.03	73.78	1.0326	237.94
18	do	1,512.0	5.16	78.05	1.0322	215.34
Total		8,804.1	4.29	377.68		1,157.70

SECOND PERIOD (80 DAYS)

No. of cow.	Group.	Total milk.	Average percentage.	Total amount.	Average specific gravity.	Total solids.
3	Prickly-pear	1,642.9	4.12	67.71	1.0338	220.17
14	do	1,060.1	4.74	50.34	1.0341	150.73
17	do	1,763.8	4.79	84.46	1.0349	255.72
19	do	1,520.2	5.26	79.96	1.0351	229.40
20	do	830.6	4.92	40.94	1.0340	119.85
Total		6,817.6	4.74	323.41		975.87
6	Sorghum silage	1,310.8	5.02	65.87	1.0347	193.02
9	do	1,990.1	4.08	81.36	1.0335	264.25
15	do	1,083.1	4.42	47.91	1.0343	150.59
16	do	1,976.7	4.46	88.28	1.0340	274.29
18	do	1,288.3	6.01	77.50	1.0339	202.59
Total		7,649.0	4.72	360.92		1,084.74

TABLE XXII.—*Milk production (second year): Prickly-pear versus cottonseed hulls*

FIRST PERIOD (80 DAYS)

No. of cow.	Group.	Total milk.	Fat in milk.		Average specific gravity.	Total solids.
			Average percentage.	Total amount.		
		Pounds.	*Per cent.*	*Pounds.*		*Pounds.*
4	Cottonseed hulls	1,771.4	5.18	91.86	1.0323	253.77
5 [a]	do	2,498.1	5.03	125.83	1.0328	356.15
10	do	1,805.7	4.44	80.31	1.0334	247.52
Total		6,075.2	4.90	298.00		857.44
8	Prickly-pear	2,340.3	3.95	92.56	1.0311	293.12
11	do	2,100.2	4.17	87.69	1.0330	278.81
12	do	1,913.9	5.72	109.55	1.0358	303.33
Total		6,354.4	4.56	289.80		875.26
1	Prickly-pear alone	1,089.2	4.11	44.75	1.0331	143.87
13 [b]	do	24.1	4.56	1.10	1.0282	3.02
Total						

[a] Period, 70 days. [b] Period, 10 days.

TABLE XXII.—*Milk production (second year): Prickly-pear versus cottonseed hulls*—Con.

SECOND PERIOD (80 DAYS)

No. of cow.	Group.	Total milk.	Fat in milk.		Average specific gravity.	Total solids.
			Average percentage.	Total amount.		
		Pounds.	*Per cent.*	*Pounds.*		*Pounds.*
4	Prickly-pear	1,270.6	4.75	60.37	1.0331	177.52
5[a]	....do	2,071.0	4.42	91.59	1.0329	280.67
10	....do	1,208.6	4.11	49.70	1.0333	160.29
Total		4,550.2	4.43	201.66	....	618.48
8	Cottonseed hulls	1,744.7	4.23	73.91	1.0307	222.73
11	....do	1,683.4	4.46	75.18	1.0330	229.38
12	....do	1,701.7	6.19	109.11	1.0350	285.28
Total		5,189.8	4.97	258.20	....	737.39
1	Prickly-pear alone	981.8	3.83	37.66	1.0328	125.83

[a] Period, 70 days.

TABLE XXIII.—*Feeds and body weights (first year): Prickly-pear versus sorghum hay*

FIRST PERIOD (80 DAYS)

No. of cow.	Group.	Feed consumed.			Body weight.		
		Grain.	Sorghum hay.	Prickly-pear.	Initial weight.	Final weight.	Gain.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	Heavy prickly-pear	314.0	296.5	11,629	823.6	833.8	10.2
2	....do	513.0	433.5	11,608	687.8	720.2	32.4
3	....do	553.0	447.5	11,214	751.6	773.8	22.2
Total		1,380.0	1,777.5	34,451	2,263.0	2,327.8	64.8
4	Medium prickly-pear	622.0	717.5	5,915	766.4	780.0	13.6
5	....do	792.0	1,016.5	5,940	725.2	772.0	46.8
6	....do	509.0	667.0	5,940	723.6	757.4	33.8
Total		1,923.0	2,401.0	17,795	2,215.2	2,309.4	94.2
8	Medium prickly-pear	752.4	676.5	5,940	712.0	753.0	41.0
9	....do	535.6	645.0	5,940	603.5	636.8	33.3
Total		1,288.0	1,321.5	11,880	1,315.5	1,389.8	74.3
10	Sorghum hay	566.2	1,250.0	....	567.5	608.0	40.5
11	....do	729.4	1,358.0	....	676.6	701.6	25.0
12	....do	793.0	1,557.5	....	717.0	743.0	26.0
Total		2,088.6	4,165.5	....	1,961.1	2,052.6	91.5
13	Prickly-pear alone	[a] 320.0	....	10,069	736.6	728.0	−8.6

[a] Cottonseed meal.

TABLE XXIII.—*Feeds and body weights (first year): Prickly-pear versus sorghum hay*—Continued

SECOND PERIOD (80 DAYS)

No. of cow.	Group.	Feed consumed.			Body weight.		
		Grain.	Sorghum hay.	Prickly-pear.	Initial weight.	Final weight.	Gain.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
1	Medium prickly-pear	268.2	612.0	4,800	782.0	774.0	− 8.0
2	....do	570.4	771.0	4,800	690.8	680.4	−10.4
3	....do	614.0	730.5	4,800	743.8	758.8	15.0
Total		1,452.6	2,113.5	14,400	2,216.6	2,213.2	− 3.4
4	Heavy prickly-pear	508.0	285.5	8,567	804.4	812.2	7.8
5	....do	863.0	427.5	9,983	813.8	832.6	18.8
6	....do	419.0	282.5	8,698	771.0	776.8	5.8
Total		1,790.0	995.5	27,248	2,389.2	2,421.6	32.4
8	Sorghum hay	771.4	1,192.0	....	751.2	728.0	−23.2
9	....do	607.7	1,204.5	....	646.0	653.2	7.2
Total		1,379.1	2,396.5	....	1,397.2	1,381.2	−10.0
10	Medium prickly-pear	464.4	652.5	4,800	610.4	624.2	13.8
11	....do	615.2	635.0	4,800	712.0	713.8	1.8
12	....do	809.3	762.0	4,800	756.8	763.6	6.8
Total		1,888.9	2,049.5	14,400	2,079.2	2,101.6	22.4
13	Prickly-pear alone	320.0	....	9,031	729.4	716.2	−13.2

TABLE XXIV.—*Feeds and body weights (second year): Prickly-pear versus sorghum silage*

FIRST PERIOD (80 DAYS)

No. of cow.	Group.	Feed consumed.				Body weight.		
		Grain.	Cotton-seed hulls	Prickly-pear.	Sorghum silage.	Initial weight.	Final weight.	Gain.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
3	Sorghum silage	731	800	....	2,274.0	731.8	777.8	46.0
14	....do	578	800	....	1,963.0	799.0	851.8	52.8
17	....do	953	800	....	2,182.5	764.4	789.4	25.0
19	....do	1,017	674	....	2,065.0	767.2	791.6	24.4
20	....do	615	800	....	2,365.0	885.8	905.4	19.6
Total		3,894	3,874	....	10,849.5	3,948.2	4,116.0	167.8
6	Prickly-pear	733	800	6,000	....	788.8	819.6	30.8
9	....do	928	800	6,000	....	719.6	737.4	17.8
15	....do	636	686	5,975	....	858.2	868.6	10.4
16	....do	732	800	6,000	....	771.8	807.4	35.6
18	....do	782	800	6,000	....	797.8	837.8	40.0
Total		3,811	3,886	29,975	....	3,936.2	4,070.8	134.6

SECOND PERIOD (80 DAYS)

No. of cow.	Group.	Grain.	Cotton-seed hulls	Prickly-pear.	Sorghum silage.	Initial weight.	Final weight.	Gain.
3	Prickly-pear	690.4	740	5,881	....	809.4	783.4	−26.0
14	....do	508.8	640	5,732	....	887.8	897.8	10.0
17	....do	865.8	720	5,852	....	815.4	824.8	9.4
19	....do	814.7	640	5,775	....	826.8	824.2	− 2.6
20	....do	422.2	800	6,000	....	919.6	932.0	12.4
Total		3,301.9	3,540	29,240	....	4,259.0	4,262.2	3.2
6	Sorghum silage	673.6	852	....	1,632	797.8	805.8	8.0
9	....do	840.0	732	....	1,664	719.0	720.0	1.0
15	....do	493.5	730	....	1,679	861.4	841.6	−19.8
16	....do	886.7	852	....	1,876	810.2	804.2	− 6.0
18	....do	791.3	832	....	1,648	839.8	823.6	−16.2
Total		3,685.1	3,998	....	8,499	4,028.2	3,995.2	−33.0

TABLE XXV.—*Feeds and body weights (second year): Prickly-pear alone versus cottonseed hulls*

FIRST PERIOD (80 DAYS)

No. of cow.	Group.	Feed consumed.			Body weight.		
		Grain.	Cottonseed hulls.	Prickly-pear.	Initial weight.	Final weight.	Gain.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
4	Cottonseed hulls	1,012	1,540		854.4	853.2	−1.2
5[a]	....do	1,318.7	1,492		863.8	870.2	6.4
10	....do	890	1,545		693.8	713.2	19.4
Total		3,220.7	4,577		2,412.0	2,436.6	24.6
8	Prickly-pear alone	1,035	720	6,000	781.6	803.8	22.2
11	....do	977	640	5,080	803.6	803.0	−.6
12	....do	1,169	720	6,000	765.8	799.2	33.4
Total		3,181	2,080	17,080	2,351.0	2,406.0	55.0
1	Prickly-pear alone.[b]	400		11,945	849.8	861.2	11.4
13	....do			9,919	695.8	671.8	−24.0

SECOND PERIOD (80 DAYS)

No. of cow.	Group.	Grain.	Cottonseed hulls.	Prickly-pear.	Initial weight.	Final weight.	Gain.
4	Prickly-pear alone	640	710	5,960	866.0	878.8	12.8
5[a]	....do	919	682	5,250	862.8	885.6	22.8
10	....do	527	492	5,467	701.0	705.0	4.0
Total		2,086	1,884	16,677	2,429.8	2,469.4	39.6
8	Cottonseed hulls	771	1,481		779.0	803.6	24.6
11	....do	789	1,348		776.6	805.2	28.6
12	....do	1,123	1,415		793.6	811.0	17.4
Total		2,683	4,244		2,349.2	2,419.8	70.6
1	Prickly-pear alone.[b]	400	[c] 1,350	10,640	844.2	850.8	6.6

[a] 70 days only. [b] Cottonseed meal. [c] Spineless cactus.

TABLE XXVI.—*Analyses of feeds used in prickly-pear feeding experiments*

FIRST YEAR (FIRST PERIOD; 80 DAYS)

Feed.	Moisture.	Ash.	Total crude protein (N×6.25).	Albuminoid protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corn chop	12.00	1.45	9.31	9.12	2.39	70.93	3.92
Wheat bran	10.40	5.95	17.72	15.25	8.35	52.95	4.63
Cottonseed meal	8.68	6.40	45.72	45.09	6.53	20.54	12.13
Sorghum hay	30.36	6.79	4.94	4.16	23.73	32.46	1.72
Prickly pear	90.96	2.27	.90	.406	1.73	4.02	.12

FIRST YEAR (SECOND PERIOD; 80 DAYS)

Feed.	Moisture.	Ash.	Total crude protein (N×6.25).	Albuminoid protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Corn chop	11.66	1.68	9.53	9.25	3.55	70.07	3.51
Wheat bran	8.98	5.86	17.81	15.17	8.15	54.02	5.18
Cottonseed meal	8.44	6.28	43.85	41.33	5.21	18.84	17.40
Sorghum hay	6.15	7.84	4.47	3.97	27.71	51.73	2.10
Prickly-pear	88.00	2.09	.83	.34	1.25	6.08	.19

TABLE XXVI.—*Analyses of feeds used in prickly-pear feeding experiments*—Continued

SECOND YEAR (FIRST PERIOD; 80 DAYS)

Feed.	Moisture.	Ash.	Total crude protein (N×6.25).	Albuminoid protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corn chop	9.81	1.37	10.76	10.48	1.89	72.19	3.98
Bran	7.16	4.94	19.32	16.35	6.65	58.75	3.13
Cottonseed meal	5.66	6.51	45.38	42.74	4.41	30.67	7.12
Cottonseed hulls	6.59	3.88	4.07	4.04	45.66	38.65	1.13
Sorghum silage	78.12	2.35	1.74	1.22	6.56	10.36	.87
Prickly-pear	92.58	1.48	.29	.22	.89	4.67	.053

SECOND YEAR (SECOND PERIOD; 80 DAYS)

Feed.	Moisture.	Ash.	Total crude protein (N×6.25).	Albuminoid protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
Corn chop	9.59	1.64	9.66	9.54	2.14	74.66	2.25
Bran	8.57	5.09	19.45	17.55	6.73	57.06	3.10
Cottonseed meal	11.31	5.71	46.66	41.24	6.41	20.76	9.13
Cottonseed hulls	6.47	2.98	4.14	3.93	46.31	39.35	.75
Sorghum silage	78.06	2.57	1.73	1.04	5.60	10.93	1.11
Prickly-pear	93.67	1.22	.313	.205	.80	3.91	.052

TABLE XXVII.—*Nutrients consumed: Group totals (first year)*

FIRST PERIOD (80 DAYS)

Feed.	Nutrient.						Total.
	Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	
Heavy prickly-pear group (cows 1, 2, 3):	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	404.80	42.83	10.99	326.28	18.03	0.87	803.80
Wheat bran	412.16	81.51	38.41	243.57	21.30	11.36	808.31
Cottonseed meal	420.07	210.31	30.04	94.48	55.80	12.10	822.80
Sorghum hay	820.01	58.17	279.42	388.22	20.25	9.18	1,569.25
Prickly-pear	3,114.37	310.06	596.00	1,384.93	41.34	168.81	5,615.51
Total	5,172.41	702.88	954.86	2,431.48	156.72	202.32	9,619.67
Medium prickly-pear group (cows 4, 5, 6):							
Corn chop	564.08	59.68	15.32	454.66	25.13	1.22	1,120.09
Wheat bran	574.34	113.59	53.52	339.41	29.68	15.83	1,126.37
Cottonseed meal	585.36	293.07	41.86	131.66	77.75	16.86	1,146.20
Sorghum hay	1,672.06	118.61	569.76	779.36	41.30	18.73	3,199.82
Prickly-pear	1,608.67	160.16	307.85	715.36	21.35	87.20	2,900.59
Total	5,004.51	745.11	988.31	2,420.45	195.21	139.84	9,493.43
Medium prickly-pear group (cows 8, 9):							
Corn chop	377.78	39.97	10.26	304.59	16.83	.82	750.16
Wheat bran	384.65	76.07	35.85	227.31	19.88	10.60	734.39
Cottonseed meal	392.04	196.28	28.03	88.18	52.07	11.29	767.89
Sorghum hay	920.29	65.28	313.59	428.96	22.73	10.31	1,761.16
Prickly-pear	1,073.95	106.92	205.52	477.58	14.26	58.21	1,936.44
Total	3,148.71	484.52	593.25	1,526.53	125.77	91.23	5,970.01
Sorghum-hay group (cows 10, 11, 12):							
Corn chop	612.66	64.82	16.64	493.81	27.29	1.32	1,216.54
Wheat bran	623.80	123.37	58.13	368.64	32.23	17.20	1,223.37
Cottonseed meal	635.77	318.30	45.46	143.00	84.45	18.31	1,245.29
Sorghum hay	2,900.85	205.78	988.47	1,352.12	71.65	32.49	5,553.36
Total	4,773.08	712.27	1,108.70	2,357.57	215.62	69.32	9,236.56

TABLE XXVII.—*Nutrients consumed: Group totals (first year)*—Continued

SECOND PERIOD (80 DAYS)

Feed.	Nutrient. Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
Heavy prickly-pear group (cows 4, 5, 6):	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	527.12	56.87	21.18	418.11	20.94	1.67	1,045.89
Wheat bran	543.12	106.27	48.63	322.34	30.91	15.75	1,067.02
Cottonseed meal	546.34	261.53	31.09	112.42	103.83	24.92	1,070.13
Sorghum hay	934.28	44.50	275.85	514.97	20.91	4.98	1,795.49
Prickly-pear	3,269.08	226.16	334.69	1,636.68	57.53	132.94	[illegible]
Total	5,819.94	695.33	711.44	3,024.52	229.32	179.20	10,660.61
Medium prickly-pear group (cows 1, 2, 3):							
Corn chop	427.74	46.14	17.19	339.28	17.00	1.30	848.71
Wheat bran	440.72	86.24	39.46	261.56	25.08	12.78	865.84
Cottonseed meal	443.34	212.22	25.23	91.22	84.25	12.12	868.37
Sorghum hay	1,983.52	94.47	565.65	1,093.31	44.38	10.57	3,811.90
Prickly-pear	1,727.64	119.52	176.88	875.52	27.76	70.29	2,997.58
Total	5,022.96	558.59	844.41	2,660.89	198.47	107.05	9,392.40
Medium prickly-pear group (cows 10, 11, 12):							
Corn chop	556.19	60.00	22.35	443.16	22.10	[illegible]	1,103.50
Wheat bran	573.06	112.13	51.31	340.11	[illegible]	16.62	1,115.84
Cottonseed meal	576.46	275.95	32.80	118.62	109.55	13.78	1,129.12
Sorghum hay	1,923.46	91.61	567.92	1,060.21	43.04	[illegible]	3,696.49
Prickly-pear	1,727.64	119.52	176.88	875.52	27.76	70.29	2,997.58
Total	5,356.81	659.21	851.26	[illegible]	[illegible]	[illegible]	[illegible]
Sorghum-hay group (cows 8, 9):							
Corn chop	406.10	43.81	16.32	322.11	16.24	2.29	805.77
Wheat bran	418.42	81.87	37.47	268.33	23.81	12.24	822.04
Cottonseed meal	420.90	201.49	23.95	86.61	79.99	11.49	824.43
Sorghum hay	2,249.12	207.12	663.07	1,276.71	50.33	11.98	4,422.33
Total	3,494.54	434.29	741.81	1,896.76	170.27	[illegible]	6,774.57

TABLE XXVIII.—*Nutrients consumed: Group totals (second year)*

FIRST PERIOD (80 DAYS)

Feed.	Nutrient. Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
Sorghum-silage group (cows 3, 14, 17, 19, 20):	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	1,170.67	139.60	22.53	937.03	51.66	3.63	2,327.18
Wheat bran	1,205.06	250.77	86.32	762.58	40.63	38.55	2,383.91
Cottonseed meal	1,224.53	589.03	57.24	398.10	95.66	34.27	2,398.83
Cottonseed hulls	3,618.70	157.07	1,768.87	1,497.30	44.55	1.16	7,088.25
Sorghum hay	2,373.87	188.78	711.73	1,124.01	94.39	56.42	4,549.20
Total	9,592.83	1,325.01	2,648.09	4,719.02	330.89	134.03	18,742.37
Prickly-pear group (cows 6, 9, 15, 16, 18):							
Corn chop	1,145.68	130.08	24.01	917.93	50.50	3.56	[illegible]
Wheat bran	1,179.35	[illegible]	84.47	746.30	39.70	37.73	2,333.03
Cottonseed meal	1,198.40	570.40	56.02	389.60	93.62	33.54	2,347.64
Cottonseed hulls	3,629.91	158.10	1,774.35	1,501.04	44.49	1.16	7,108.01
Prickly-pear	2,224.13	86.93	266.73	1,390.83	20.98	29.98	4,015.65
Total	9,377.49	1,203.65	2,205.63	4,954.70	253.41	96.97	18,091.85

TABLE XXVIII.—*Nutrients consumed: Group totals (second year)*—Continued

FIRST PERIOD (80 DAYS)—continued

Feed.	Nutrient.						
	Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
Prickly-pear group (cows 8, 11, 12):	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	956.28	114.09	20.04	765.43	42.20	2.97	1,901.01
Wheat bran	984.38	204.85	70.51	622.93	33.19	31.49	1,947.35
Cottonseed meal	1,000.29	481.16	46.76	325.19	78.14	27.99	1,959.53
Cottonseed hulls	1,942.93	84.66	949.73	803.92	23.92	.62	3,805.78
Prickly-pear	1,267.34	49.53	152.01	797.64	15.37	11.96	2,293.85
Total	6,151.22	934.29	1,239.05	3,315.11	192.82	75.03	11,907.52
Cottonseed-hulls group (cows 4, 5, 10):							
Corn chop	968.28	115.52	20.29	775.03	42.73	3.01	1,924.86
Wheat bran	996.73	207.42	71.39	630.74	33.60	31.89	1,971.77
Cottonseed meal	1,012.83	487.20	47.35	329.27	79.12	28.34	1,984.11
Cottonseed-hulls	4,275.38	186.28	2,089.86	1,769.01	52.64	1.37	8,374.54
Total	7,253.22	996.42	2,228.89	3,504.05	208.09	64.61	14,255.28

SECOND PERIOD (80 DAYS)

Feed.	Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
Sorghum-silage group (cows 6, 9, 15, 16, 18):							
Corn chop	1,110.60	118.66	26.29	917.12	27.76	1.47	2,201.90
Wheat bran	1,123.13	238.92	82.67	700.92	38.08	23.34	2,207.06
Cottonseed meal	1,089.47	573.17	78.74	255.02	112.40	66.58	2,175.38
Cottonseed hulls	3,739.33	165.52	1,851.47	1,573.21	29.98	8.40	7,367.91
Sorghum silage	1,804.68	147.03	475.94	928.94	94.34	58.64	3,569.[illegible]
Total	8,927.21	1,243.30	2,515.11	4,375.21	302.56	158.43	17,121.8[illegible]
Prickly-pear group (cows 3, 14, 17, 19, 20):							
Corn chop	995.05	106.32	23.55	821.71	24.87	1.32	1,972.8[illegible]
Wheat bran	1,006.28	214.07	74.07	628.00	34.12	20.91	1,977.4[illegible]
Cottonseed meal	976.12	513.50	70.55	228.48	100.70	59.65	1,949.02
Cottonseed hulls	3,310.96	146.56	1,639.37	1,392.99	26.55	7.43	6,523.86
Prickly-pear	1,850.89	90.64	233.92	1,143.28	26.32	32.16	3,377.2[illegible]
Total	8,139.30	1,071.09	2,041.46	4,214.46	212.56	121.47	15,800.34
Prickly-pear group (cows 4, 5, 10):							
Corn chop	628.62	67.17	14.88	519.11	15.71	.83	1,246.[illegible]
Wheat bran	635.71	135.24	46.79	396.74	21.55	13.21	1,249.2[illegible]
Cottonseed meal	616.66	324.43	44.57	144.34	63.62	37.69	1,231.3[illegible]
Cottonseed hulls	1,762.11	78.00	872.48	741.35	14.13	3.96	3,472.0[illegible]
Prickly-pear	1,055.65	51.70	133.42	652.07	15.01	18.34	1,92[illegible]
Total	4,698.75	656.54	1,112.14	2,453.61	130.02	74.03	9,125.0[illegible]
Cottonseed-hulls group (cows 8, 11, 12):							
Corn chop	808.54	86.39	19.14	667.68	20.21	1.07	1,603.03
Wheat bran	817.66	173.94	60.19	510.29	27.72	16.99	1,606.79
Cottonseed meal	793.15	417.28	57.32	185.66	81.83	48.47	1,583.71
Cottonseed hulls	3,969.41	175.70	1,965.40	1,670.01	31.83	8.91	7,821.2[illegible]
Total	6,388.76	853.31	2,102.05	3,033.64	161.59	75.44	12,614.7[illegible]

TABLE XXIX.—*Nutrients digested: Group totals (first year)*

FIRST PERIOD (80 DAYS)

Feed.	Nutrient.						
	Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Heavy prickly-pear group (cows 1, 2, 3):							
Corn chop	346.27	38.41	7.58	203.99	15.96	0.87	651.08
Wheat bran	255.71	74.06	18.74	150.45	12.08	11.30	522.40
Cottonseed meal	304.04	205.98	12.51	64.11	47.21	12.10	645.95
Sorghum hay	417.07	29.51	162.93	222.84	11.84	9.18	865.37
Prickly-pear	1,802.76	261.82	304.90	862.10	24.51	168.81	3,424.90
Total	3,155.85	609.78	506.66	1,543.49	103.60	202.32	6,127.70
Medium prickly-pear group (cows 4, 5, 6):							
Corn chop	492.78	44.45	11.82	405.69	20.37	1.02	976.27
Wheat bran	363.90	85.71	29.18	228.93	17.55	15.83	741.13
Cottonseed meal	432.70	238.39	19.48	97.59	65.70	10.80	873.69
Sorghum hay	931.00	49.98	371.31	451.04	25.24	18.73	1,847.90
Prickly-pear	951.00	112.30	176.01	480.25	13.22	87.20	1,825.93
Total	3,171.38	530.83	607.80	1,606.07	143.05	139.84	6,250.92
Medium prickly-pear group (cows 8, 9):							
Corn chop	330.03	29.77	7.91	269.03	13.60	.82	681.16
Wheat bran	243.72	57.40	19.55	153.32	11.77	10.00	476.30
Cottonseed meal	239.80	159.65	13.05	65.34	46.01	11.29	558.14
Sorghum hay	512.42	27.51	204.37	248.59	13.88	10.34	1,017.08
Prickly-pear	634.89	74.98	117.51	324.62	8.83	58.21	1,219.04
Total	2,010.56	349.31	362.39	1,060.90	94.09	91.23	3,968.78
Sorghum-hay group (cows 10, 11, 12):							
Corn chop	540.79	50.74	13.22	427.09	22.30	1.32	1,055.46
Wheat bran	399.36	97.84	32.65	243.41	19.29	17.20	809.75
Cottonseed meal	474.85	272.12	21.80	103.73	73.41	18.31	966.22
Sorghum hay	1,632.02	91.14	663.56	567.05	44.24	34.49	3,230.60
Total	3,047.02	511.84	731.23	1,341.28	151.24	69.32	7,028.13

SECOND PERIOD (80 DAYS)

Feed.	Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
Heavy prickly-pear group (cows 4, 5, 6):							
Corn chop	450.90	51.00	14.61	338.29	16.21	1.07	872.68
Wheat bran	336.95	96.56	23.73	199.11	17.52	15.75	689.62
Cottonseed meal	395.44	250.14	12.95	76.29	87.84	14.92	843.58
Sorghum hay	509.37	22.59	160.85	273.29	12.23	4.95	983.31
Prickly-pear	1,892.31	190.97	171.22	1,031.25	31.15	132.94	3,449.84
Total	3,584.97	617.26	383.36	1,918.23	164.95	170.26	6,839.01
Medium prickly-pear group (cows 1, 2, 3):							
Corn chop	373.67	34.37	13.26	299.75	13.74	1.36	736.15
Wheat bran	279.24	65.07	21.52	175.42	14.55	12.78	569.88
Cottonseed meal	327.72	172.62	11.74	67.59	74.45	12.11	669.23
Sorghum hay	1,104.42	39.87	381.07	633.57	27.12	10.57	2,197.16
Prickly-pear	1,021.32	83.82	101.13	595.77	17.19	70.26	1,888.83
Total	3,106.37	395.69	529.32	1,772.43	147.35	107.08	6,058.25
Medium prickly-pear group (cows 10, 11, 12):							
Corn chop	485.88	44.69	17.24	389.77	17.87	1.76	957.21
Wheat bran	303.09	84.61	27.98	229.43	19.32	16.62	741.02
Cottonseed meal	428.12	224.46	15.27	87.89	96.80	15.74	868.28
Sorghum hay	1,070.99	38.60	370.11	614.39	20.30	10.25	2,130.64
Prickly-pear	1,021.32	83.82	101.13	595.12	17.19	70.29	1,888.83
Total	3,369.40	476.18	531.73	1,916.57	177.47	114.63	6,585.98
Sorghum hay group (cows 8, 9):							
Corn chop	358.46	34.30	12.97	278.59	13.19	1.29	695.80
Wheat bran	267.88	64.93	21.04	193.97	14.25	12.14	544.21
Cottonseed meal	314.37	173.26	11.48	62.85	71.43	11.49	643.80
Sorghum hay	1,261.36	47.44	445.78	703.28	31.07	11.98	2,504.91
Total	2,205.07	318.93	491.27	1,238.69	129.94	36.90	4,391.78

TABLE XXX.—*Nutrients digested: Group totals (second year)*

FIRST PERIOD (80 DAYS)

Feed.	Nutrient.						
	Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
Sorghum-silage group (cows 3, 14, 17, 19, 20):	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	1,065.31	106.14	14.23	871.44	44.43	3.63	2,105.18
Wheat bran	795.34	193.09	35.39	541.43	25.60	38.55	1,629.40
Cottonseed meal	942.89	488.89	20.03	310.52	89.92	34.27	1,886.52
Cottonseed hulls	1,483.67	9.46	831.37	509.08	35.19	1.16	2,869.93
Sorghum silage	1,519.28	84.95	412.80	786.81	65.13	56.42	2,925.19
Total	5,806.49	882.53	1,313.82	3,019.28	260.27	134.03	11,416.42
Prickly-pear group (cows 6, 9, 15, 16, 18):							
Corn chop	1,042.57	103.88	13.93	852.84	43.48	3.56	2,060.26
Wheat bran	778.37	188.97	34.63	529.87	25.05	37.73	1,594.62
Cottonseed meal	922.77	478.46	19.61	303.89	88.00	33.54	1,846.27
Cottonseed hulls	1,488.26	9.49	833.94	510.66	33.57	1.16	2,877.08
Prickly-pear	1,369.63	62.21	114.69	1,001.58	17.78	20.98	2,586.87
Total	5,601.60	843.01	1,016.80	3,198.84	207.88	96.97	10,965.10
Prickly-pear group (cows 8, 11, 12):							
Corn chop	870.21	86.71	11.62	711.85	36.29	2.97	1,719.65
Wheat bran	649.69	157.73	28.91	442.28	20.91	31.49	1,331.01
Cottonseed meal	770.22	399.36	16.37	253.65	73.45	27.99	1,541.04
Cottonseed hulls	796.60	5.08	446.37	273.33	18.90	.62	1,540.90
Prickly-pear	780.43	35.44	65.35	570.71	10.13	11.96	1,474.02
Total	3,867.15	684.32	568.62	2,251.82	159.68	75.03	7,606.62
Cottonseed-hulls group (cows 4, 5, 10):							
Corn chop	881.13	87.80	11.77	720.78	36.75	3.01	1,741.24
Wheat bran	657.84	159.71	29.27	447.83	21.17	31.89	1,347.71
Cottonseed meal	779.88	404.38	16.37	256.83	74.37	28.34	1,560.37
Cottonseed hulls	1,752.91	11.18	982.23	601.46	41.59	1.37	3,390.74
Total	4,071.76	663.07	1,039.84	2,026.90	173.86	64.61	8,040.06

SECOND PERIOD (80 DAYS)

Feed.	Dry matter.	Crude protein (N×6.25).	Crude fiber.	Nitrogen-free extract.	Ether extract.	Amids.	Total.
Sorghum-silage group (cows 6, 9, 15, 16, 18):							
Corn chop	1,010.65	90.18	15.25	852.92	23.87	1.47	1,994.34
Wheat bran	741.27	183.97	33.89	497.65	23.99	23.34	1,504.11
Cottonseed meal	838.89	475.73	27.56	198.92	105.66	66.58	1,713.34
Cottonseed hulls	1,533.13	9.93	870.19	534.89	23.68	8.40	2,980.22
Sorghum silage	1,193.40	66.16	276.05	650.26	65.09	58.64	2,309.60
Total	5,317.34	825.97	1,222.94	2,734.64	242.29	158.43	10,501.60
Prickly-pear group (cows 3, 14, 17, 19, 20):							
Corn chop	905.50	80.80	13.66	764.19	21.39	1.32	1,786.86
Wheat bran	664.14	164.83	30.37	445.88	21.50	20.91	1,347.63
Cottonseed meal	751.61	426.20	24.69	178.21	94.66	59.05	1,535.02
Cottonseed hulls	1,357.49	8.79	770.50	473.62	20.97	7.43	2,638.80
Prickly-pear	1,139.78	64.86	100.56	818.02	17.34	32.16	2,172.72
Total	4,818.52	745.48	939.78	2,679.92	175.86	121.47	9,481.03
Prickly-pear group (cows 4, 5, 10):							
Corn chop	572.04	51.05	8.63	482.77	13.51	.83	1,128.83
Wheat bran	419.57	104.13	19.78	281.69	13.58	13.21	851.96
Cottonseed meal	474.83	269.28	15.60	112.59	59.80	37.69	969.79
Cottonseed hulls	722.47	4.68	410.07	252.06	11.16	3.96	1,404.40
Prickly-pear	650.07	37.00	57.36	466.56	9.89	18.34	1,239.22
Total	2,838.98	466.14	510.84	1,595.67	107.94	74.03	5,593.00
Cottonseed-hulls group (cows 8, 11, 12):							
Corn chop	735.77	65.66	11.10	620.94	17.38	1.07	1,451.92
Wheat bran	539.66	133.93	24.68	362.31	17.40	16.99	1,095.05
Cottonseed meal	610.73	346.34	20.06	144.81	76.92	48.47	1,247.33
Cottonseed hulls	1,627.46	10.54	923.74	567.80	25.15	8.91	3,163.60
Total	3,513.62	556.47	979.58	1,695.86	136.91	75.44	6,957.88

TABLE XXXI.—*Composition of feeds used in digestion trials*

Feed.	No. of digestion trial.	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corn chop	1 to 4	12.33	1.27	9.12	2.17	71.01	3.50
Do	5	11.79	1.23	9.40	1.83	72.95	2.80
Wheat bran	1 to 4	9.77	6.70	15.38	10.05	53.02	2.80
Do	5	9.91	6.02	17.80	8.07	53.50	5.08
Cottonseed meal	1 to 4	9.53	6.22	44.93	6.82	18.50	4.10
Do	5	10.27	6.15	40.60	6.08	23.15	14.00
Sorghum hay	1 to 5	6.22	8.84	[illegible].65	29.50	47.71	14.39
Prickly-pear (air-dried)	1	5.87	20.60	6.47	10.04	53.77	2.08
Do	2	8.20	18.78	6.88	10.60	53.21	2.35
Do	3	9.05	16.06	4.95	13.15	54.37	2.23
Do	4	8.09	10.47	4.31	12.52	57.17	1.52
Do	5	8.24	18.24	5.27	10.04	50.07	1.44
Refused sorghum hay	1 (cow 11)	5.58	7.95	4.07	33.10	47.91	2.14
Do	1 (cow 12)	5.27	15.43	6.08	28.05	41.73	1.33
Do	3 (cow 11)	5.51	13.02	4.20	31.95	40.48	2.84
Do	3 (cow 12)	5.59	8.99	3.89	31.60	47.13	2.78
Do	5 (cow 1)	7.90	15.61	6.53	33.19	34.75	2.80
Common salt	1 to 5	3.37	Sodium chlorid, 94.75 per cent; undetermined, 1.88 per cent.				2.02

TABLE XXXII.—*Composition of feces voided and air-dried during digestion trials*

No. of cow.	No. of digestion trial.	Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
11	1	5.82	16.12	10.37	20.20	45.16	2.33
12	1	5.48	20.65	9.47	17.10	45.34	1.90
1	2	4.08	30.30	4.23	16.33	43.78	1.28
2	2	6.24	20.52	4.58	16.23	49.59	2.94
12	3	8.05	20.31	8.09	17.55	42.17	2.93
11	3	6.93	15.25	8.07	18.72	47.87	3.16
1	4	5.18	22.11	3.22	16.89	50.02	2.58
[illegible]	4	5.48	26.71	2.05	19.06	39.80	1.90
1	5	5.58	20.27	8.21	17.70	45.64	2.70
11	5	4.73	22.79	2.84	16.31	51.03	2.30

TABLE XXXIII.—*Results of digestion trial 1, cow 11, on a ration of hay and grain*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	22	19.2874	0.2794	2.0064	0.4774	15.7342	0.7700
Wheat bran	22	19.8500	1.4740	3.5860	2.7110	11.6644	1.1176
Cottonseed meal	22	19.9034	1.3184	9.8840	1.5004	4.0700	3.0800
Sorghum hay	180	168.8040	15.9120	10.2750	53.1000	85.8780	3.7440
Refused sorghum hay	24.2	22.8490	1.9239	.9849	8.0247	11.5942	.3219
Common salt	.625	.5922	.5922				
Total (less refused hay)		205.5880	17.7021	24.4597	49.2041	105.7724	8.3897
Feces:							
Wet	379.85	78.6309	13.4586	8.6579	16.8650	37.7041	1.9453
Air-dried	83.49						
Digested		126.9571	4.2435	15.8018	32.3991	68.0683	6.4444
Digested (per cent)		61.75	23.97	64.60	65.77	64.35	76.81

TABLE XXXIV.—*Results of digestion trial 1, cow 12, on a ration of hay, grain, and medium prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	30	26.3010	0.3810	2.7360	0.6510	21.4830	1.0500
Wheat bran	30	27.0690	2.0100	4.6140	3.0150	15.9060	1.5240
Cottonseed meal	30	27.1410	1.8660	13.4790	2.0460	5.5500	4.2000
Prickly-pear (wet)	600	56.7603	12.4218	3.9014	6.5968	32.4233	1.4170
Prickly-pear (air-dried)	60.3						
Sorghum hay	100	93.7800	8.8400	5.6500	29.5000	47.7100	2.0800
Refused sorghum hay	20	18.9460	3.0860	1.2160	5.7300	8.3460	.5080
Common salt	.625	.5922	.5922				
Total (less refused hay)		212.6975	23.0250	29.1644	36.0788	114.7263	9.7010
Feces:							
Wet	388.20	75.0773	16.4023	7.5220	13.6302	36.0136	1.5092
Air-dried	79.43						
Digested		137.6202	6.6227	21.6424	22.4486	78.7127	8.1918
Digested (per cent)		64.70	28.76	74.21	62.22	68.69	84.45

TABLE XXXV.—*Results of digestion trial 2, cow 1, on a ration exclusively of prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Prickly-pear (wet)	1.170	106.5371	21.8186	7.9932	12.3151	61.8194	2.5908
Prickly-pear (air-dried)	116.18						
Common salt	.625	.5922	.5922				
Total		107.1293	22.4108	7.9932	12.3151	61.8194	2.5908
Feces:							
Wet	324.90	44.7851	14.1471	1.9750	7.6245	20.4409	.5976
Air-dried	46.69						
Digested		62.3442	8.2637	6.0182	4.6906	41.3785	1.9932
Digested (per cent)		58.20	36.87	75.29	38.09	66.93	76.93

TABLE XXXVI.—*Results of digestion trial 2, cow 2, on a ration of grain, hay, and heavy prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	18	15.7806	0.2286	1.0416	0.3906	12.8898	0.6350
Wheat bran	18	16.2414	1.2060	2.7084	1.8090	9.5430	.9124
Cottonseed meal	18	16.2846	1.1196	8.0874	1.2276	3.3300	2.5200
Prickly-pear (wet)	1.080						
Prickly-pear (air-dried)	107.24	98.3391	20.1397	7.3781	11.3674	57.0024	2.3915
Sorghum hay	45	42.2010	3.9780	2.5425	13.2750	21.4095	.9360
Common salt	.625	.5922	.5922				
Total		189.4389	27.2641	22.4180	28.0695	104.2953	7.3219
Feces:							
Wet	423.30						
Air-dried	80.47	75.4487	16.5929	3.5246	13.0602	39.9051	2.3018
Digested		113.9902	10.6712	18.8934	15.0093	64.3902	5.0201
Digested (per cent)		60.17	39.14	84.28	53.47	61.74	67.99

TABLE XXXVII.—*Digestion trial 3, cow 11, on a ration of grain, hay, and medium prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	22	19.2874	0.2794	2.0064	0.4774	15.7512	0.7730
Wheat bran	22	19.8506	1.4740	3.3836	2.2110	11.6844	1.1176
Cottonseed meal	22	19.9034	1.3684	9.8846	1.5004	4.0700	3.0800
Prickly-pear (wet)	600	54.5154	10.1658	2.9670	7.8821	32.5894	.9111
Prickly-pear (air-dried)	59.54						
Sorghum hay	100	95.7800	8.8400	5.6500	29.5000	47.7100	2.0800
Refused sorghum hay	10	9.4190	1.5020	.4260	3.1930	4.0480	.2750
Common salt	.625	.5922	.5922				
Total (less refused hay)		198.4800	21.2178	23.4656	38.3759	107.7400	7.6897
Feces:							
Wet	361.40	71.8773	15.8763	6.7930	13.7188	33.1988	2.2904
Air-dried	78.17						
Digested		126.6027	5.3415	16.6726	24.6571	74.5412	5.3993
Digested (per cent)		63.79	25.17	71.05	64.25	69.19	70.18

TABLE XXXVIII.—*Results of digestion trial 3, cow 12, on a ration of grain and hay*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	30	26.3010	0.381	2.736	0.651	21.483	1.030
Wheat bran	30	27.0690	2.010	4.614	3.015	15.906	1.524
Cottonseed meal	30	27.1410	1.866	13.479	2.046	5.550	4.220
Sorghum hay	160	150.0480	14.1440	9.0400	47.200	76.3360	3.3280
Refused sorghum hay	15.25	14.3975	1.3710	.5932	4.8190	7.1875	.4270
Common salt	.625	.5922	.5922	....	....	....	....
Total (less refused hay)	....	216.7537	17.6222	29.2758	48.0930	112.0877	9.6750
Feces:							
Wet	443.10	79.8820	13.0891	6.9265	16.0674	41.0868	2.7122
Air-dried	85.83	....	....	....	....	....	....
Digested	....	136.8717	4.5331	22.3493	32.0256	71.0009	6.9628
Digested (per cent)	....	63.15	25.72	76.34	66.59	63.34	71.97

TABLE XXXIX.—*Results of digestion trial 4, cow 1, on a ration of grain, hay, and heavy prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	14	12.2738	0.1778	1.2768	0.3038	10.0254	0.4900
Wheat bran	14	12.6322	.9380	2.1532	1.4070	7.4228	.7112
Cottonseed meal	14	12.6658	.8708	6.2902	.9548	2.5900	1.9600
Prickly-pear (wet)	1,200	121.4315	21.7602	5.6944	16.5414	75.5330	1.9025
Prickly-pear (air-dried)	132.12	....	....	....	....	....	....
Sorghum hay	50	46.890	4.420	2.825	14.750	23.855	1.040
Common salt	.625	.5922	.5922	....	....	....	....
Total	....	206.4855	28.7590	18.2396	33.9570	119.4262	6.1037
Feces:							
Wet	477.80	....	....	....	....	....	....
Air-dried	87.56	83.0243	19.3595	2.8194	14.7889	43.7975	2.2590
Digested	....	123.4612	9.3995	15.4202	19.1681	75.6287	3.8447
Digested (per cent)	....	59.79	32.68	84.54	56.45	63.33	62.99

TABLE XL.—*Results of digestion trial 4, cow 3, on a ration exclusively of prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Prickly-pear (wet)	1,200	121.4315	21.7602	5.6944	16.5414	75.5330	1.9025
Prickly-pear (air-dried)	132.12						
Common salt	.625	.5922	.5922				
Total		122.0237	22.3524	5.6944	16.5414	75.5330	1.9025
Feces:							
Wet	301.95	42.7513	13.4378	1.8318	8.6208	18.0015	.8549
Air-dried	45.23						
Digested		79.2724	8.9146	3.8626	7.9206	57.5315	1.0431
Digested (per cent)		64.96	39.88	67.83	47.88	76.17	54.83

TABLE XLI.—*Results of digestion trial 5, cow 1, on a ration of grain, hay, and medium prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	14	12.3494	0.1722	1.3160	0.2562	10.2130	0.3970
Wheat bran	14	12.6126	.8428	2.4920	1.2138	7.4900	.5740
Cottonseed meal	14	12.5622	.8610	5.7344	.8512	3.2410	1.8746
Prickly-pear (wet)	600	59.9559	11.9180	3.4434	6.5601	36.6361	1.3983
Prickly-pear (air-dried)	65.34						
Sorghum hay	100	93.7800	8.8400	5.6500	29.5000	47.7100	2.0800
Refused sorghum hay	3.8	3.4998	.5932	.2481	1.2612	1.3205	.0768
Salt	.625	.5922	.5922				
Total (less refused hay)		188.3525	22.6330	18.3877	37.1201	103.9696	6.2421
Feces:							
Wet	453.35						
Air-dried	82.87	78.2459	16.7149	6.8036	14.6680	37.8219	2.2375
Digested		110.1066	5.9181	11.5841	22.4521	66.1477	4.0046
Digested (per cent)		58.46	26.15	63.00	60.49	63.62	64.15

Table XLII.—*Results of digestion trial 5, cow 11, on a ration of grain, hay, and heavy prickly-pear*

Feed.	Quantity.	Constituent.					
		Dry matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Corn chop	22	19.4062	0.2706	2.0680	0.4026	16.0490	0.0160
Wheat bran	22	19.8198	1.3244	3.9160	1.9074	11.7700	.9020
Cottonseed meal	22	19.7406	1.3530	9.0112	1.3376	5.0930	2.9458
Prickly-pear (wet)	1,050	....	....	....	....	....	....
Prickly-pear (air-dried)	114.34	104.9183	20.8556	6.0257	11.4797	64.1104	2.4469
Sorghum hay	50	46.8900	4.4200	2.8250	14.7500	23.8550	1.0400
Common salt	.625	.5922	.5922	....	....	....	....
Total	....	211.3671	28.8158	23.8459	29.8773	120.8774	7.9597
Feces:							
Wet	393.05	....	....	....	....	....	....
Air-dried	86.35	82.2656	19.6792	2.4523	14.0837	44.0644	1.9860
Digested	....	129.1015	9.1366	21.3936	15.7936	76.8130	5.9647
Digested (per cent)	....	61.08	31.71	89.72	52.86	63.55	75.02

PLATE F

Opuntia cyanella, one of the principal species of prickly-pear used in these experiments.

Fig. 1.—Mature joint; ½ natural size on a photographic background.
Fig. 2.—A flower bud; natural size.
Fig. 3.—Young joint showing rudimentary leaves.
Fig. 4.—Flower; ½ natural size.
Fig. 5.—A fruit; natural size.

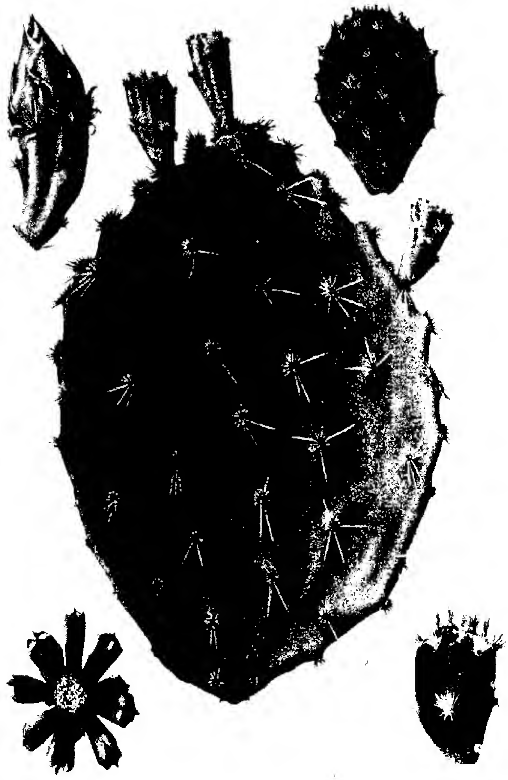

PLATE LXI

Fig. 1.—Singeing prickly-pear with a gasoline torch.

Fig. 2.—Cutting prickly-pear with a hoe, the blade of which is bent so as to be in line with the handle.

PLATE LXII

Fig. 1.—Loading prickly-pear on a wagon.
Fig. 2.—Type of cows used.

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A NASTURTIUM WILT CAUSED BY BACTERIUM SOLANACEARUM

By Mary K. Bryan,
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INTRODUCTION

On July 21, 1914, some badly wilted nasturtiums (*Tropaeolum majus*) were received from Dr. John Arthur Luetscher of Baltimore, Md., who wrote concerning them:

> Seven years ago I raised a fine lot of nasturtiums, but in the last six years I have hardly been able to get a blossom, although the plants have been in the same soil and several times in the same plat. The leaves wither and the plant dies.

The plants, which were of the dwarf variety and much-branched, were poorly developed, and the leaves mostly wilted, yellowed, or dead (Pl. LXIII). The stems had a peculiar translucent or water-soaked appearance, allowing the vascular bundles to show as darkened streaks beneath the unbroken epidermis. When the stem was cut across, there oozed from these bundles a grayish white viscid slime which became brown on standing.

ISOLATION OF THE ORGANISM

On cross-sectioning such stems the vessels were found to be clogged with bacteria, often every bundle being entirely occluded. Agar-poured plates gave pure cultures of a white bacterial organism. Inoculations made from colonies on these plates into nasturtium stems produced signs of the disease—i. e., wilted leaves and water-soaked stems—within seven days (Pl. LXIV). From one of these stems the organism was reisolated on agar-poured plates and again produced typical wilt within four days when inoculated into healthy young nasturtiums, using subcultures from single colonies.

NATURE OF THE ORGANISM

Cultural work was then begun, but it was not until the growth on potato cylinders began to blacken that the identity of the organism with *Bacterium solanacearum* [1] was suspected. To test this hypothesis, inoculations were at once made into tomatoes (*Lycopersicon esculentum*), the only available plants being rather old. The result was the formation of numerous adventive roots in the vicinity of the needle pricks and the slow wilt of a few leaflets. Vessels were browned and filled with these

[1] Originally described by Erwin F. Smith as *Bacillus solanacearum* under the supposition that it was peritrichiate, but afterwards transferred by him to the genus Bacterium, in accordance with his system of nomenclature *in his* Bacteria in Relation to Plant Diseases. v. 1, p. 171. Washington, D. C., 1905. (Carnegie Inst. Wash. Pub. 27.)

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bacteria, as shown by microscopic examination and by poured plates. The plants then outgrew the disease. While not conclusive, these results did not contradict my supposition, since the organism plated from tobacco (*Nicotiana* spp.) and tomato often gives no more marked results when inoculated into old plants.

FURTHER CROSS-INOCULATIONS

A virulent strain of *B. solanacearum* obtained from tobacco from Creedmore, N. C., during the summer of 1914 was then available for comparison, and inoculations were made with this into nasturtiums of the tall variety by means of needle pricks from young agar subcultures. After 10 days all plants showed one or more wilted leaves and an abundance of the characteristic adventive roots near the point of inoculation (Pl. LXV, fig. 1). A month later one of these stems had produced adventive roots at intervals from 7 inches above the pricks to 20 inches below them, and in one case where the stem hung near the ground they were 3 inches long and had taken hold in the soil. Bacteria were present the entire length of the stem, which was now entirely leafless. Inoculations into dwarf nasturtiums produced a more rapid wilt but no adventive roots.

On young tobacco, prick inoculations with the nasturtium organism caused in five days an internal dark streak (visible on the surface) running several inches up and down the stem from the point of inoculation and the wilt of one or two leaves, but the plants always recovered. Check pricks produced no effect.

Inoculations with the nasturtium organism into *very young* tomato plants resulted in the rapid and complete wilt of the plants (Pl. LXVI, fig. 1). The entire vascular system became gorged with bacteria. Poured plates gave pure cultures of *Bacterium solanacearum*, as determined by cultures on typical media and by successful reinoculations into both tomato and tobacco plants.

TESTS ON OTHER PLANTS

A variety of plants were tested for susceptibility. Prick inoculations were made with both the Creedmore tobacco organism and the nasturtium organism into pelargoniums, soy beans (*Glycine hispida*), and lettuce (*Lactuca sativa*), all with negative results. Owing to the fact that Honing[1] in Sumatra has reported this disease on several composites and in young teak trees (Verbenaceae), inoculations were made on hot-house ageratum and on common cultivated verbena. Both became diseased but rather slowly. After 10 days the ageratum showed distortion of the leaves, one half being paler and smaller than the other, and after

[1] Honing, J. A., Een geval van slijmziekte in de djattibibit. Meded. Deli Proefstat. te Medan, Jrg. 7, Afl. 1, p. 12–15, also Naschrift, p. 59, 1912. See review in Smith, Erwin F., Bacteria in relation to plant diseases, v. 3, p. 254.

15 days complete wilt of several leaves occurred. The results were checked under the microscope. For the most part the plants outgrew the disease. Verbenas showed wilt within two weeks, and after three weeks the tips, as well as the leaves, for 2 inches below the point of inoculation, were completely wilted. Agar-poured plates from one of these stems gave pure cultures of *B. solanacearum*.

NATURAL METHODS OF INFECTION

The organism may enter the nasturtium plant through wounded roots or shoots or through the stomata. To demonstrate root infection, six nasturtium seeds were planted in each of four pots. Two pots were watered with a suspension from young agar cultures of the nasturtium organism and then covered with fresh soil. The others were held as checks. When the plants had four good leaves, the soil was worked in all the pots deeply enough to break some roots. Six weeks later one plant in an inoculated pot was badly wilted, and 10 days later four others succumbed, while those in the check pots were perfectly healthy. One week later all but 3 of the 12 plants in the inoculated pots had succumbed. Sections from stems of a number of these wilting plants were examined under the microscope. The vessels were seen to be clogged with bacteria, and there was the usual tissue disorganization.

Before the organism was identified, spray experiments were started to determine whether stomatal infections could be obtained. Well-grown plants of both tall and dwarf varieties of nasturtiums were sprayed in cages with a suspension from 3-day agar-slant cultures. Repeated spraying with sterile water kept the plants moist for 30 hours, after which they were removed from the cages. Six days later a few minute brownish spots appeared on the leaves, but these did not enlarge materially. Four weeks later, however, one plant was characteristically wilted, and within three weeks from this time all of the dwarf plants and one of the tall ones had succumbed, with characteristic bacterial infection of the vascular system.

Another experiment was made with young plants, each bearing two large leaves. They were sprayed in cages with suspensions from young agar cultures and kept moist for 48 hours. Four days after the experiment was started the large leaves all showed decided brown spotting and water-soaked areas. The spots centered about the stomata in every case examined, and often, but not always, they were marginal. After two weeks the spots had coalesced in many places and appeared to be affecting the small veins of the blade. Poured plates from such spots gave typical colonies of *B. solanacearum*. Portions of the leaves in both these stages were embedded, sectioned, and stained, and bacterial foci found in the substomatic chamber, thus demonstrating stomatal infection. In the younger stages the bacteria appear in the stomatal opening, as well as in the large chamber beneath (fig. 1). In older stages the

collapsed parenchyma is evidence of their presence, and careful search finds them lying closely appressed to the cell walls when they are not abundant in the intercellular spaces. In this stage they are also in the neighboring vessels of the leaf (fig. 2). In stained sections the walls of the vessels often show injury by taking a deeper stain than normal ones, even when the bacteria do not appear to have penetrated to their interior.

One leaf, which showed browning of some of the smaller veins, was sectioned at various points on the veins and petiole. The bacteria were numerous in the vessels of the browned area and for some distance below, but thinned out downward so that none were found in the base of the petiole or in the stem of the plant. In another case the bacteria

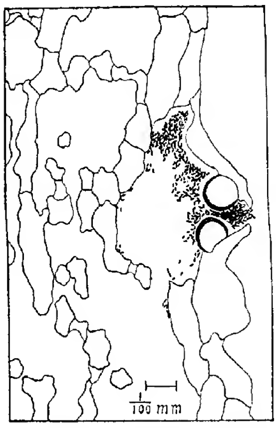

FIG. 1.—Section of nasturtium leaf four days after spraying with suspension of *Bacterium solanacearum*. Serially adjacent sections show bacteria throughout the substomatic chamber.

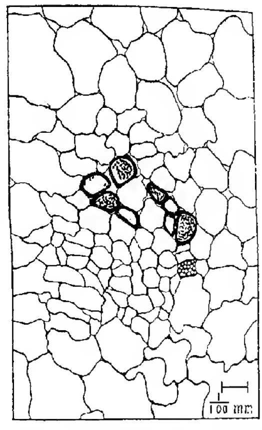

FIG. 2.—Cross section of a vein of nasturtium leaf, showing vascular infection nine days after spraying with suspension of *Bacterium solanacearum*.

were traced in the vessels all the way from the wilting leaf blade to the stem of the plant. Three plants in this set finally wilted completely. An early stage of vascular occlusion and cavity formation in the stem of a nasturtium, like that shown in Plate LXIII, is illustrated in figure 3.

Several attempts to produce stomatal infection on tomatoes and tobacco were made, but without success.

SUSCEPTIBILITY OF THE NASTURTIUM

From comparative needle-prick inoculations on nasturtium, tomato, and tobacco with the Creedmore tobacco organism, which was beginning to lose its virulence, it would appear that the nasturtium is very susceptible to infection by *B. solanacearum*, since it wilted readily, while

tobacco and tomato, except when very young, wilted only slightly and recovered quickly. The converse of this experiment led to the same conclusion—i. e., that the nasturtium is more susceptible than the tomato or tobacco—because the organism isolated from the nasturtium was more infectious to the nasturtium than to tobacco or tomato. Possibly the susceptibility of nasturtium may be due to the great succulence of the nasturtium stems. The Medan (Sumatra) tobacco organism,

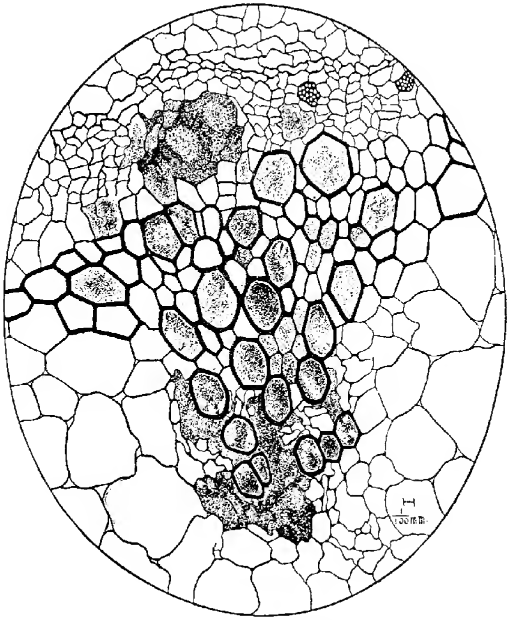

Fig. 3.—Cross section of stem of one of the infected nasturtiums from Baltimore, Md., showing the bacterial invasion of a bundle with the beginning of bacterial cavities. Two sieve plates are visible in the center phloem.

which had been extremely virulent but had been on media for a longer time than the Creedmore organism, was not able to infect either nasturtiums or tomatoes.

EFFECT ON THE TISSUES

The more tender parts of badly diseased plants become so translucent that the occluded browned vessels may be seen clearly through the water-soaked but unshriveled parenchyma (Pl. LXVI, fig. 3). In other cases the course of the affected bundle or bundles is marked superfi-

cially by sunken, reddish brown streaks or patches (Pl. LXV, fig. 2). Generally in the case of prick inoculations on nasturtiums of the tall variety adventive roots are formed at various points on the stem. These remain rudimentary except where the stems are near the ground, when they may become functioning roots. Check pricks failed to produce any root formation. No adventive roots occurred on any of the inoculated plants of the dwarf variety.

MORPHOLOGY OF THE NASTURTIUM ORGANISM

The organism is a short rod with rounded ends, 0.6 by 0.8 to 1.3μ, motile by means of one to three polar flagella. No spores or capsules occur on any media. Chains of 10 to 15 individuals are formed in 0.5 and 1 per cent salt bouillon. Similar chains are formed in 0.5 per cent salt bouillon by the Creedmore tobacco organism.

STAINING REACTIONS

With carbol fuchsin polar staining is obtained. The organism does not stain by Gram's method and is not acid-fast. Flagella were demonstrated by Löwitt's flagella stain.

CULTURAL CHARACTERS

In all the cultural tests made with this organism it agrees substantially with *Bacterium solanacearum* Erw. Sm. Growth was studied in the following media: Agar plates, slants, and stabs; gelatin plates and stabs; potato cylinders; beef bouillon; fermentation tubes containing water + 1 per cent Witte's peptone + 1 per cent dextrose, saccharose, lactose, maltose, mannit, or glycerin; milk; litmus milk; Cohn's solution; Uschinsky's solution; and Fermi's solution.

Growth is retarded by 0.5 per cent of sodium chlorid in beef bouillon, is prevented by 2 per cent, and is very weak in 1 per cent. This is true also for the Creedmore tobacco organism, which was used for comparison. No record has been previously given for *B. solanacearum* in this medium.

TEMPERATURE RELATIONS

The optimum for growth is about 30° C. No growth occurs at 39° C., very weak growth at 12° C., and none at 10° C. The thermal death-point lies between 48° and 52° C.

DESICCATION OF THE ORGANISM

When dried on sterile covers from young peptone-beef-bouillon cultures and kept in the dark at room temperature (21° C.), most covers gave growth after 24 hours when dropped into suitable bouillon, very few after 2 days', and none after 3 days' drying. The bacteria from 24-hour bouillon cultures were more sensitive to drying than those from 8-day-old cultures.

SUMMARY

The nasturtium is subject to a bacterial wilt disease, observed for the first time in the summer of 1914, which prevents blossoming, stunts the plants, and finally kills them. It is caused by a bacterium that in all morphological, cultural, and infectious characters agrees with *Bacterium solanacearum* Erw. Sm.

Cross-inoculations on the tomato and tobacco produced successful and typical wilt of these plants, while inoculations on the nasturtium with a virulent strain of *B. solanacearum*, isolated from tobacco, gave typical nasturtium wilt.

Infection takes place from infected soil through broken roots, but stomatal infection has also been demonstrated.

Cultivated ageratums and verbenas were found susceptible to infection with both the nasturtium and the Creedmore (N. C.) tobacco strains of *B. solanacearum*.

This paper adds another family to those already known to be subject to *B. solanacearum*. Described from the tomato, the potato, and the eggplant in 1896 by Dr. Erwin F. Smith,[1] this organism has now been proved infectious to one or more species of each of the following families: Solanaceae, Compositae, Leguminosae, Verbenaceae, Euphorbiaceae, Bignonaceae, and Geraniaceae.

If tomatoes, eggplants, peppers, potatoes, peanuts, or tobacco have shown this wilt disease, they should not be followed by nasturtiums.

[1] Smith, Erwin F. A bacterial disease of the tomato, eggplant, and Irish potato (Bacillus solanacearum, n. sp.). U. S. Dept. Agr., Div. Veg. Physiol. and Path. Bul. 12, 28 p., 2 pl. (1 col.). 1896.

PLATE LXIII

Bacterially wilted nasturtium plant from Baltimore, Md.


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PLATE LXIV

Nasturtium plants four days after inoculation by needle pricks on the stem, using a pure culture of the bacteria cultivated from a plant infected like that shown in Plate LXIII.

PLATE LXV

Fig. 1.—Nasturtium plant (tall variety) 13 days after inoculation with *Bacterium solanacearum* from Creedmore (N. C.) tobacco, showing wilt of the foliage and development of roots near needle pricks.

Fig. 2.—Stem of a nasturtium plant inoculated with *Bacterium solanacearum* from tobacco, showing dark sunken stripe following line of infected bundle.


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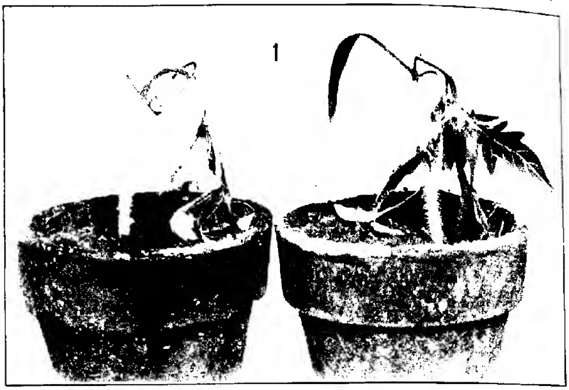
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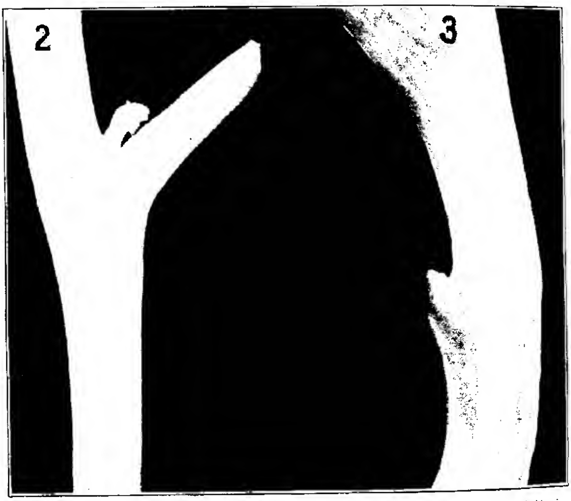
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PLATE LXVI

Fig. 1.—Young tomato plants six days after inoculation by needle pricks with the nasturtium organism, *Bacterium solanacearum*.

Fig. 2.—Normal nasturtium stem enlarged to show uniform (unstriped) appearance.

Fig. 3.—A nasturtium stem inoculated with *Bacterium solanacearum*, showing striping due to bacterial invasion of the bundles.

PHOSPHORUS METABOLISM OF LAMBS FED A RATION OF ALFALFA HAY, CORN, AND LINSEED MEAL[1]

By E. L. Ross, *Fellow in Chemistry*, M. H. Keith, *Assistant*, and H. S. Grindley, *Chief, Division of Animal Nutrition, Department of Animal Husbandry, College of Agriculture and the Agricultural Experiment Station of the University of Illinois*

INTRODUCTION

The ultimate object of the investigations of which this article is a partial report was to determine the influence of different quantities of protein upon the nutrition of young growing lambs. The differences in the amounts of protein consumed were secured by varying the proportions of corn and linseed meal in the rations. Such differences in the quantities of protein were therefore necessarily accompanied by corresponding differences in the quantities of phosphorus ingested by the lambs. The experimental data relating to the phosphorus metabolism of the lambs when weighing, on the average, 115 pounds are given in this paper. For convenience, the original designation of the lots as "low-protein," "medium-protein," and "high-protein" is retained.

As to the relative availability of organic and inorganic phosphorus, there is a wide difference of opinion among investigators. With regard to lambs, there is some definite evidence of the assimilation of inorganic phosphates of calcium in the work reported by Köhler and his associates.[2]

The question of the form in which the phosphorus is excreted is a matter of interest, whatever the form of ingestion. Elimination in any of the organic forms in which it was ingested would probably mean lack of assimilation or incomplete use after assimilation. Giacosa[3] says that all absorbed phytin is split with the formation of phosphates, part of the phosphates appearing in the urine and part in the feces. Bergmann[4] reports that the subcutaneous injection of glycerophosphate in lambs was followed by complete elimination as inorganic phosphates.

It is usually said that in herbivora phosphorus is eliminated almost entirely by way of the intestine. Bergmann[4] found complete elimi-

[1] The authors wish to acknowledge their indebtedness to Prof. W. C. Coffey and Mr. A. D. Emmett, of the University of Illinois, for helpful suggestions and assistance in the planning and conducting of this experiment.

[2] Köhler, A., Honcamp, F., Just, M., et al. Über die Assimilation des Kalkes und der Phosphorsäure aus verschiedenen Kalkphosphaten durch wachsende Tiere. *In* Landw. Vers. Sta., Bd. 61, Heft 5/6, p. 451–479. 1905.

—— —— and Eisenkolbe, P. Weitere Untersuchungen über die Assimilation der Phosphorsäure und des Kalkes aus Kalkphosphaten durch wachsende Tiere. *In* Landw. Vers. Stat., Bd. 65, Heft 5/6, p. 349–380. 1907.

[3] Giacosa, P. Sulla fitina (sale calcico-magnesiaco dell' acido anidrossimetilendifosforico) e suo comportarsi nell' organismo. *In* Gior. R. Accad. Med. Torino, ann. 67, no. 7/8, p. 414–426. 1904.

[4] Bergmann, W. Ueber die Ausscheidung der Phosphorsäure beim Fleisch- und Pflanzenfresser. *In* Arch. Exp. Path. u. Pharmakol., Bd. 47, Heft 1/2, p. 77–81. 1901.

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nation by this path in lambs after subcutaneous injection of either inorganic phosphates or glycerophosphates. However, the observations of Le Clerc and Cook[1] on rabbits seem to form an exception to this general rule.

The utilization and final fate of phosphorus compounds is probably in part determined by the amount and nature of the accompanying food constituents. That the amount of phosphorus in the ration affects the use made of protein by growing pigs is indicated by the work of Hart, McCollum, and Fuller.[2] Work done in this laboratory by Williams and Emmett[3] does not show a variation in the percentage or the distribution of phosphorus in the bodies or the parts of the bodies of growing pigs resulting from variations in the amount of protein consumed.

DESCRIPTION OF THE METABOLISM EXPERIMENT

ANIMALS AND RATIONS USED

Six high-grade Shropshire lambs were used in this experiment, which was a metabolism test of 12 successive days. Two representative lambs 9 months old were chosen from each of three lots which had been fed from the time of weaning, June 25, until this experiment began, December 23, on the same feeds, though the proportions fed were different. The rations of the three lots, both before and during the metabolism test, consisted of alfalfa hay, shelled corn, and old-process linseed meal. The quantity of alfalfa hay depended upon the appetite of the individual. Until December 3 of the main feeding experiment there were fed 1.5 pounds of concentrates for each 100 pounds of live weight, after which time actual increase of concentrates with the increase of live weight was deemed unwise. The daily allowance of concentrates, then, remained constant during the metabolism test. The concentrates of the ration for the low-protein lot consisted of 95 per cent of shelled corn and 5 per cent of linseed meal; for the medium-protein lot the concentrates consisted of 75 per cent of corn and 25 per cent of linseed meal; and for the high-protein lot they consisted of equal parts of corn and linseed meal. Water was accessible at all times. The amounts of feed and water consumed were determined by the difference between the quantities offered and those refused.

CARE OF ANIMALS

On December 17, 1910, each lamb was put into a metabolism cage which was large enough to allow the animal to turn around easily. To each lamb was strapped a canvas bag in which the feces were collected.

[1] Le Clerc, J. A., and Cook, F. C. Metabolism experiments with organic and inorganic phosphorus. *In* Jour. Biol. Chem., v. 2, no. 3, p. 203–216. 1906.

[2] Hart, E. B., McCollum, E. V., and Fuller, J. G. The rôle of inorganic phosphorus in the nutrition of animals. Wis. Agr. Exp. Sta. Research Bul. 1, 38 p., 7 fig. 1909.

[3] Williams, R. H., and Emmett, A. D. A study of the phosphorus content of growing pigs with special reference to the influence of the quantity of protein consumed. Ill. Agr. Exp. Sta. Bul. 171, p. 205–230, 5 fig. 1914.

The bag was lined with oilcloth in order to prevent loss of moisture and solid material. The feces were taken from these bags at 2 p. m. daily. Under the wire grating of each cage there was a galvanized-iron tray, which acted as a collecting funnel for the urine. The lambs were fed twice each day, at 7 a. m. and at 4 p. m. The concentrates were fed about 20 minutes before the alfalfa hay, and the grain orts were collected just before the hay was fed. The hay orts of the previous feeding were collected before each new feeding. The metabolism test proper extended from December 23 to January 3, inclusive.

METHODS OF ANALYSIS

The methods of analysis used in this experiment were essentially the same as the official methods of analysis of the Association of Official Agricultural Chemists [1] for all determinations except for the different forms of phosphorus.

The methods used in determining the different forms of phosphorus in the feeds and feces were as follows:

(a) METHOD OF MAKING A 0.2 PER CENT HYDROCHLORIC-ACID EXTRACT.—A sample of suitable size (about 100 gm. of feces or 50 gm. of feed) was divided about equally between two 500 c. c. centrifuge bottles. A little powdered thymol and 300 c. c. of a 0.2 per cent hydrochloric-acid solution were added to each bottle. The bottles were wired spoke-wise to a bicycle wheel, which was revolved at the rate of about 38 revolutions per minute, and were shaken in this manner for from 12 to 14 hours.

The bottles were then opened, the sides of each washed from a pipette with 25 c. c. of the acid solution, and then they were placed in the centrifuge, running at the rate of about 1,700 revolutions per minute, for 10 minutes. The clear solution in each bottle was carefully decanted into a 3-liter measuring flask. Then 100 c. c. of the 0.2 per cent acid solution were added to each bottle. The bottles were shaken till the contents were homogeneous and the sides washed again with 25 c. c. of the solution. This process of extraction was repeated nine times. Generally a tenth extraction was made and tested qualitatively. The solution in the measuring flask was then made up to the mark with the 0.2 per cent hydrochloric-acid solution and thoroughly mixed. If the solution in the flask was quite thick with sediment, it was allowed to settle and then the liquid was decanted through a 10-inch qualitative filter. The filtering was repeated till the filtrate was perfectly clear.

(b) TOTAL ACID-SOLUBLE PHOSPHORUS DETERMINATION.—Triplicate samples of 100 c. c. each of the clear 0.2 per cent hydrochloric-acid extract were evaporated to dryness in weighed, ignited 3-inch porcelain dishes, and ashed. The total phosphorus of this ash was determined in the usual manner.

(c) ACID-INSOLUBLE PHOSPHORUS was determined by subtracting the total acid-soluble phosphorus from the total phosphorus of the feeds or feces.

(d) INORGANIC ACID-SOLUBLE PHOSPHORUS DETERMINATION.—Triplicate samples of 150 c. c. of the acid extract were each treated with 25 c. c. of magnesia mixture. This magnesia mixture was added slowly, drop by drop, while the solution was being stirred. After the solutions had stood for 15 minutes, 20 c. c. of ammonia (sp. gr. 0.90) were added to each beaker and the solutions allowed to stand for 12 hours. At the end of this time the solutions were filtered through double 11 cm. filters and the

[1] Wiley, H. W., et al. Official and provisional methods of analysis, Association of Official Agricultural Chemists. U. S. Dept. Agr. Bur. Chem. Bul. 107 (rev.), 272 p., 11 fig. 1908.

beakers and precipitates washed a number of times with a 2½ per cent ammonium-hydroxid solution. The inside filters and precipitates were returned to their respective beakers, treated with 25 c. c. of dilute nitric acid, and the filters well shredded with the stirring rods. Clean beakers were put under the funnels, the solutions filtered through their respective funnels, and the filters washed repeatedly with boiling distilled water. To each solution 15 c. c. of ammonia (sp. gr. 0.90) were added. The solutions were then made slightly acid with pure nitric acid. The phosphorus was precipitated with acid ammonium molybdate and the phosphorus determination continued as usual.

(e) ORGANIC ACID-SOLUBLE PHOSPHORUS was determined by subtracting the inorganic acid-soluble phosphorus from the total acid-soluble phosphorus.

It should be said in this connection that since these different forms of phosphorus were determined in connection with this investigation it has been clearly demonstrated in this and other laboratories that the above methods, or, in fact, any other methods at present known for the separation and estimation of inorganic and organic phosphorus in vegetable substances, are not strictly accurate and give only approximate results. It is the opinion of the authors that the above methods are as accurate for this purpose as any known at present and that the results obtained are probably a fair approximation to the true values for the inorganic and organic phosphorus in the materials examined.

LIVE WEIGHTS AND TOTAL GAINS IN BODY WEIGHT

The lambs were weighed the three days immediately before they were put into the digestion crates and the three days immediately following the metabolism test. The average of each of these three weights is given in Table I, together with the total gain in weight of each lamb from December 15 to January 5.

TABLE I.—*Live weights and total gains in live weights (in pounds) of lambs in metabolism test*

Item.	Low-protein ration.		Medium-protein ration.		High-protein ration.	
	Lamb No. 468.	Lamb No. 463.	Lamb No. 462.	Lamb No. 458.	Lamb No. 453.	Lamb No. 451.
Live weight Jan. 5	110.0	106.5	118.0	131.0	114.5	118.5
Live weight Dec. 15	108.5	102.5	115.0	125.5	112.0	115.5
Total gain	1.5	4.0	3.0	5.5	2.5	3.0

WEIGHTS AND COMPOSITION OF FEEDS CONSUMED

The quantities of the feeds consumed by the individual lambs during the 12 days of the metabolism test, expressed in grams per day, are given in Table II. Lamb 463 ingested a ration relatively very high in roughage, while lambs 468 and 462 ingested a ration relatively low in roughage. Lamb 458 ingested the largest quantity of total feed. The chemical composition of the feeds consumed is given in Table III.

TABLE II.—*Rations consumed by lambs in metabolism test*

[Results expressed in grams per day]

Ration.	Lamb No.	Hay consumed.	Concentrates consumed.	Ratio of roughage to concentrates.
Low-protein	468	494.9	625.9	1 : 1.26
	463	759.9	556.5	1 : 0.73
Average		627.4	591.2	1 : 0.94
Medium-protein	462	593.8	758.5	1 : 1.28
	458	793.7	820.0	1 : 1.03
Average		693.8	789.3	1 : 1.14
High-protein	453	700.5	735.0	1 : 1.05
	451	694.1	747.8	1 : 1.08
Average		697.3	741.4	1 : 1.06

TABLE III.—*Chemical composition (in percentage) of feeds consumed by lambs*

Feed.	Dry matter.	Protein.[a]	Nonprotein.[b]	Ether extract.	Carbohydrates.	Ash.	Phosphorus.	Total nitrogen.
Alfalfa hay	85.18	12.50	2.16	1.78	60.60	8.14	0.216	2.46
Corn	88.56	6.89	0.93	4.05	75.46	1.23	.269	1.30
Linseed meal	90.06	31.79	[d]3.16	6.38	43.04	5.32	.881	5.83
Do.[c]	89.46	30.88	[d]3.14	6.36	43.29	5.41	.864	5.69

[a] Protein nitrogen × 6.25.
[b] Nonprotein nitrogen × 4.7.
[c] This sample was fed during period 3.
[d] Calculated from Armsby's data.

NUTRIENTS DIGESTED DURING THE METABOLISM TEST

The apparent coefficients of digestibility of the nutrients and the amounts of nutrients apparently digested during the metabolism test were calculated from the weights and the analyses of the feeds, orts, and feces. The weights and composition of the feces are given in Tables IV and V, respectively. The apparent coefficients of digestibility of the nutrients are given in Table VI. The quantity of dry matter, protein, nonprotein, ether extract, carbohydrates, ash, phosphorus, and nitrogen apparently digested daily by each lamb during the 12 days of the metabolism test, together with the calculated values for the metabolizable energy, or fuel values expressed in Calories, are given in Table VII.

TABLE IV.—*Weights of feces and urine of lambs*

[Results expressed in grams per day]

Material.	Low-protein ration.		Medium-protein ration.		High-protein ration.	
	Lamb No. 468.	Lamb No. 463.	Lamb No. 462.	Lamb No. 458.	Lamb No. 453.	Lamb No. 451.
Feces	639	974	879	1,322	985	1,021
Urine	486	663	896	813	1,263	1,167

TABLE V.—*Chemical composition (in percentage) of the feces of lambs*

Ration.	Lamb No.	Dry matter.	Crude protein.	Ether extract.	Carbohydrates.	Ash.	Phosphorus.	Total nitrogen.	Metabolic nitrogen.
Low-protein	468	32.31	6.80	1.90	19.77	4.13	0.401	1.088	0.567
	463	32.65	6.26	1.90	20.85	3.93	.332	1.001	.557
Average	......	32.48	6.53	1.90	20.31	4.03	.367	1.045	.562
Medium-protein	462	32.95	6.30	1.91	20.71	4.30	.416	1.007	.504
	458	27.64	5.50	1.20	17.67	3.46	.342	.880	.432
Average	......	30.30	5.90	1.56	19.19	3.88	.379	.944	.468
High-protein	453	35.55	6.00	1.59	20.73	4.43	.520	.960	.422
	451	31.68	6.05	1.50	19.99	4.32	.522	.969	.438
Average	......	33.62	6.03	1.55	20.36	4.38	.521	.964	.430

TABLE VI.—*Apparent coefficients of digestibility of the nutrients of the rations of lambs*

Constituent.	Low-protein ration.			Medium-protein ration.			High-protein ration.		
	Lamb No. 468.	Lamb No. 463.	Average.	Lamb No. 462.	Lamb No. 458.	Average.	Lamb No. 453.	Lamb No. 451.	Average.
Dry matter	78.9	72.1	75.5	75.5	74.0	74.8	74.5	74.3	74.4
Protein	61.3	56.6	59.0	68.2	63.9	66.1	73.7	73.1	73.4
Nonprotein	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ether extract	65.0	50.1	57.6	63.2	69.0	66.1	68.8	70.2	69.5
Carbohydrates	83.5	76.7	80.1	79.1	77.5	78.3	76.5	76.4	76.5
Ash	45.6	44.6	45.1	42.0	43.6	42.8	45.2	45.3	45.3
Phosphorus	12.9	2.5	7.7	18.5	11.5	15.0	10.0	8.0	9.0
Nitrogen	67.3	64.1	65.7	73.3	69.9	71.6	77.9	77.3	77.6

TABLE VII.—*Amounts of nutrients apparently digested by the lambs and the metabolizable energy of the digested nutrients*

Constituent.	Low-protein ration.			Medium-protein ration.			High-protein ration.		
	Lamb No. 468.	Lamb No. 463.	Average.	Lamb No. 462.	Lamb No. 458.	Average.	Lamb No. 453.	Lamb No. 451.	Average.
Dry matter.....gm	769.78	823.58	796.68	890.62	1,039.30	964.96	932.36	934.75	933.56
Protein.....gm	71.91	79.34	75.63	119.05	128.90	123.98	165.23	169.15	167.19
Nonprotein.....gm	16.86	22.05	19.46	24.38	29.43	26.91	30.65	30.91	30.78
Ether extract.....gm	22.62	18.22	20.42	28.78	35.39	32.09	34.53	35.91	35.22
Carbohydrates.....gm	637.24	670.04	653.64	663.10	806.63	734.87	662.78	660.09	661.44
Ash.....gm	22.21	30.85	26.53	27.36	35.58	31.47	35.91	36.59	36.25
Phosphorus.....gm	.38	.10	.24	.83	.59	.71	.57	.47	.52
Nitrogen.....gm	14.37	17.42	15.90	24.38	27.04	25.71	33.23	33.75	33.49
Metabolizable energy[a].....Calories	3,239	3,390	3,315	3,626	4,348	3,987	3,891	3,909	3,900

[a] The metabolizable energy of a ration is the energy that can be liberated and utilized in the animal body, or the gross energy less the energy contained in the feces, urine, and intestinal gases. The metabolizable energy of the rations has been calculated by multiplying the weights of the digestible nutrients by the following factors: Digestible proteins and nonproteins, 4.1; digestible carbohydrates, 4.2; and digestible ether extract, 8.8.

PHOSPHORUS OF THE RATIONS

PHOSPHORUS CONTENT OF THE FEEDS OFFERED

The percentages of the different forms of phosphorus found in the different feeds of the rations are stated in Table VIII.

TABLE VIII.—*Different forms of phosphorus in the feeds of lambs*

[Results expressed in percentage of the fresh substance]

Feed.	Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus.		
			Total.	Inorganic.	Organic.
Alfalfa hay	0.216	0.058	0.158	0.149	0.009
Corn	.269	.133	.136	.031	.105
Linseed meal	.881	.652	.229	.127	.102

It is significant that, while the corn had 1.25 times as much total phosphorus as the alfalfa hay, the linseed meal had 4.07 times as much as the hay; also that the corn had 2.30 times as much acid-insoluble phosphorus as the hay, and the linseed meal had 11.23 times as much. The linseed meal had a much higher content of total phosphorus than either the hay or the corn, and this increased phosphorus was largely in the acid-insoluble form. Neither the corn nor the linseed meal had as high content of inorganic acid-soluble phosphorus as the hay.

Since the gradations in protein given to the three lots were made by increasing the amount of linseed meal in relation to corn and since the linseed meal was richer than the corn in total phosphorus, in acid-insoluble phosphorus, and in organic acid-soluble phosphorus, while the two concentrates were practically identical in organic acid-soluble phosphorus, it is evident that the high-protein lot received concentrates which were richer in all forms of phosphorus with the exception of the organic acid-soluble form than were those received by the medium-protein lot. The same was true of the medium-protein lot relative to the low-protein lot, but the three lots were offered practically the same quantities of organic acid-soluble phosphorus.

AMOUNTS OF PHOSPHORUS INGESTED

The average daily quantities of the different forms of phosphorus ingested by each lamb as calculated from the weights and analyses of the feeds and the orts are given in Table IX.

TABLE IX.—*Average daily amounts of the different forms of phosphorus ingested by lambs*

[Results expressed in grams per day]

Ration.	Lamb No.	Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus.		
				Total.	Inorganic.	Organic.
Low-protein	468	2.94	1.24	1.70	0.99	0.71
	463	3.34	1.31	2.03	1.34	.69
Average	....	3.14	1.27	1.87	1.17	.70
Medium-protein	462	4.48	2.29	2.19	1.34	.85
	458	5.11	2.58	2.53	1.61	.92
Average	....	4.80	2.44	2.36	1.47	.89
High-protein	453	5.68	3.25	2.43	1.61	.82
	451	5.79	3.31	2.48	1.64	.84
Average	....	5.74	3.28	2.46	1.63	.83

The low values for total and for inorganic acid-soluble phosphorus with lamb 468 are to be accounted for by his relatively low consumption of hay.

The lot differences in the total phosphorus ingested were due primarily to differences in the amounts of linseed meal in the rations offered, but are affected also by the fact that the low-protein lot did not ingest as much of the concentrates as the others, as is shown from the data of Table II.

The lot variations in the amount of acid-insoluble phosphorus ingested were greater than in that of the total phosphorus. The amount of this form of phosphorus ingested by the medium-protein lot was 192 per cent, and by the high-protein lot 258 per cent of the amount ingested by the low-protein lot. This large variation between the low- and medium-protein lots was due mainly to a difference in the amount of concentrates consumed and to the richness of the concentrates in this form of phosphorus, owing to its higher content of linseed meal. The main cause for the difference between the amounts of acid-insoluble phosphorus ingested by the medium- and high-protein lots was the fact that the acid-insoluble phosphorus content of the concentrates differed considerably, the difference between the quantities of hay or concentrates consumed by the two lots amounting to little.

The amount of acid-soluble phosphorus ingested by the medium-protein lot was 126 per cent and that by the high-protein lot was 132 per cent of that of the low-protein lot. Since the acid-soluble phosphorus content of the concentrates did not differ much, being for the low-, medium-, and high-protein lots 0.141, 0.160, and 0.183 per cent, respectively, the differences between the lots were due largely to the variation in the weights of hay and concentrates consumed.

The amount of inorganic acid-soluble phosphorus ingested by the medium-protein lot was 126 per cent and the amount ingested by the high-protein lot was 139 per cent of the amount ingested by the low-protein lot. The causes of this variation were the same as those for the total phosphorus.

The lot average of the organic acid-soluble phosphorus for the medium-protein lot was 127 per cent and that for the high-protein lot was 119 per cent of the lot average for the low-protein lot. The cause for the difference between the low- and medium-protein lots is traceable to both the amount of the feeds ingested and their richness in this form of phosphorus. The medium-protein lot exceeded the low-protein lot in the consumption of both hay and concentrates, but mainly concentrates; and the hay contained only 0.009 per cent of this form of phosphorus, while the concentrates fed to both the low-protein and the medium-protein lots contained 0.105 per cent. The difference between the organic acid-soluble phosphorus for the medium- and the high-protein lots was due chiefly to a difference in the amount of concentrates consumed. This is clear when it is noted that the average consumption for the medium-protein lot was 693.8 gm. of alfalfa hay and 789.3 gm. of concentrates, while that for the high-protein lot was 697.3 gm. of hay, and 741.4 gm. of concentrates, the medium-protein lot exceeding the high-protein lot in the consumption of concentrates. The organic acid-soluble phosphorus content of the concentrates fed the two lots also had a small influence.

The percentage distribution of the ingested phosphorus among the different kinds is recorded in Table X. It will be noted that the relative amounts of the four different forms of phosphorus ingested by the three lots of lambs varied decidedly.

TABLE X.—*Relative amounts of the different forms of phosphorus ingested by lambs*

[Results expressed in percentage of the total phosphorus ingested]

Ration.	Lamb No.	Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus.		
				Total.	Inorganic.	Organic.
Low-protein	468	100	42.2	57.8	33.7	24.1
	463	100	39.2	60.8	40.1	20.7
Average		100	40.7	59.3	36.9	22.4
Medium-protein	462	100	51.1	48.9	29.9	19.0
	458	100	50.5	49.5	31.5	18.0
Average		100	50.8	49.2	30.7	18.5
High-protein	453	100	57.2	42.8	28.4	14.4
	451	100	57.2	42.8	28.3	14.5
Average		100	57.2	42.8	28.3	14.5

RELATIONS BETWEEN THE PERCENTAGE OF PHOSPHORUS AND OF PROTEIN IN THE FEEDS

Attention has been called to the fact that, while the rations were primarily planned to furnish marked differences in the protein received by the different groups of animals, such differences in the protein were necessarily accompanied by corresponding differences in the amounts and kinds of phosphorus received. The percentages of protein and phosphorus and the ratios of phosphorus to protein in the several feeds offered and in the concentrates of the different lots are given in Table XI.

Table XI.—*Phosphorus and protein content of the feeds compared*

Feed.	Phosphorus.	Protein.	Ratio of phosphorus to protein.
	Per cent.	*Per cent.*	
Alfalfa hay	0.216	12.50	1 : 57.9
Corn	.269	6.89	1 : 25.6
Linseed meal	.881	31.79	1 : 36.1
Concentrates of Lot I	.300	8.14	1 : 27.1
Concentrates of Lot II	.422	13.12	1 : 31.1
Concentrates of Lot III	.575	19.34	1 : 33.6

It is evident from the data given in Table XI that there are marked differences between the ratios of phosphorus to protein in alfalfa hay, corn, and linseed meal. On the other hand, the ratios between the phosphorus and protein in the concentrates fed Lots I, II, and III are not markedly dissimilar.

PHOSPHORUS IN THE FECES AND URINE

PHOSPHORUS CONTENT OF THE FECES

The percentages of the different forms of phosphorus found in the feces are given in Table XII. The average daily excretion of the different forms of phosphorus in the feces and of the total phosphorus in the urines is given in Table XIII.

TABLE XII.—*Different forms of phosphorus in the feces*

[Results expressed in percentage of the fresh substance]

Ration.	Lamb No.	Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus.		
				Total.	Inorganic.	Organic.
Low-protein	468	0.400	0.065	0.335	0.321	0.014
	463	.333	.049	.284	.263	.021
Average	....	.367	.057	.310	.292	.018
Medium-protein	462	.416	.042	.374	.338	.036
	458	.342	.065	.277	.254	.023
Average	....	.379	.053	.326	.296	.030
High-protein	453	.520	.109	.411	.390	.021
	451	.521	.078	.443	.402	.041
Average	....	.520	.093	.427	.396	.031

TABLE XIII.—*Different forms of phosphorus excreted by lambs*

[Results expressed in grams per day]

Ration.	Lamb No.	Feces.					Urine: Total phosphorus.
		Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus.			
				Total.	Inorganic.	Organic.	
Low-protein	468	2.56	0.42	2.14	2.05	0.09	0.016
	463	3.24	.48	2.76	2.56	.20	.015
Average	....	2.90	.45	2.45	2.30	.15	.016
Medium-protein	462	3.66	.37	3.29	2.97	.32	.012
	458	4.52	.86	3.66	3.36	.30	.018
Average	....	4.09	.61	3.48	3.17	.31	.015
High-protein	453	5.11	1.07	4.04	3.83	.21	.018
	451	5.32	.80	4.52	4.10	.42	.014
Average	....	5.22	.94	4.28	3.97	.31	.016

As is usually the case with herbivora, by far the largest part of the phosphorus was excreted in the feces. With these lambs the quantities of phosphorus in the urine were all less than 0.02 gm. per day, while those in the feces ranged from 2.6 to 5.3 gm. per day. Evidently, therefore, the phosphorus of the feces is not unassimilated, but in large part is assimilated material which has been excreted into the intestine. Probably the data of the acid-insoluble form more nearly represent those of the undigested phosphorus than do any other figures.

The amounts of total phosphorus excreted and of fecal phosphorus increased with the quantities of phosphorus and protein fed, but the amounts in the urine remained practically constant.

The data for the different forms of phosphorus in the feces, the total phosphorus in the urine, and the total phosphorus stored in the body, expressed in percentage of the total phosphorus ingested, are given in Table XIV.

TABLE XIV.—*Different forms of phosphorus in the feces of lambs, the total phosphorus in their urine, and the total phosphorus stored*

[Results expressed in percentage of total phosphorus ingested]

Ration.	Lamb No.	Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus. Total.	Acid-soluble phosphorus. Inorganic.	Acid-soluble phosphorus. Organic.	Total phosphorus.	Stored phosphorus.
Low-protein	468	87.1	14.3	72.8	69.7	3.1	0.5	12.4
	463	97.0	14.4	82.6	76.6	6.0	.4	2.5
Average	......	92.1	14.4	77.7	73.2	4.5	.4	7.5
Medium-protein	462	81.7	8.3	73.4	66.3	7.1	.3	18.0
	458	88.5	16.8	71.7	65.8	5.9	.4	11.1
Average	......	85.1	12.5	72.6	66.1	6.5	.3	14.6
High-protein	453	90.0	18.9	71.1	67.4	3.7	.3	9.7
	451	91.9	13.8	78.1	70.8	7.3	.2	7.9
Average	......	91.0	16.4	74.6	69.1	5.5	.2	8.8

It is evident from the data given in Table XIV that, on an average, 89.4 per cent of the total phosphorus ingested by the lambs was excreted in the feces. On an average, 75 per cent of the ingested phosphorus of the feeds was excreted in the feces in a form soluble in 0.2 per cent hydrochloric-acid solution, while 69.5 per cent of the total phosphorus consumed was excreted in the feces in the inorganic form.

On account of the small number of animals in each group and the marked individual differences in the data for the different forms of phosphorus in the feces, the total phosphorus in the urine, and the total phosphorus stored in the body expressed in percentage of the total phosphorus ingested, it is impossible to make out significant group differences due to the differences in the quantities of protein and phosphorus ingested.

The data for the percentage distribution of the different forms of phosphorus in the feces in percentage of the total phosphorus are given in Table XV.

TABLE XV.—*Distribution of the forms of phosphorus in the feces of lambs*

[Results expressed in percentage of the total phosphorus]

Ration.	Lamb No.	Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus. Total.	Inorganic.	Organic.
Low-protein	468	100.0	16.4	83.6	80.1	3.5
	463	100.0	14.8	85.2	79.0	6.2
Average		100.0	15.6	84.4	79.6	4.8
Medium-protein	462	100.0	10.1	89.9	81.1	8.8
	458	100.0	19.0	81.0	74.3	6.7
Average		100.0	14.5	85.5	77.7	7.8
High-protein	453	100.0	20.9	79.1	75.0	4.1
	451	100.0	15.0	85.0	77.1	7.9
Average		100.0	17.9	82.1	76.1	6.0

It is apparent that there are no significant group differences in the distribution of the different forms of phosphorus in the feces. The variations within the lots are as great as between lots. The significant facts shown by these results are the relatively small percentage of acid-insoluble phosphorus and the relatively large percentage of acid-soluble inorganic phosphorus in the feces.

The results for the forms of phosphorus in the feces in percentage of the amounts of the same forms ingested are given in Table XVI.

TABLE XVI.—*The forms of phosphorus in the feces of lambs*[a]

[Results expressed in percentage of the amounts of the same forms ingested]

Ration.	Lamb No.	Total phosphorus.	Acid-insoluble phosphorus.	Acid-soluble phosphorus. Total.	Inorganic.	Organic.
Low-protein	468	87.1	33.9	125.9	207.1	12.7
	463	97.0	36.6	136.0	191.0	29.0
Average		92.1	35.3	131.0	199.1	20.9
Medium-protein	462	81.7	16.2	149.3	221.5	37.7
	458	88.5	33.3	144.7	208.7	32.6
Average		85.1	24.8	147.0	215.1	35.2
High-protein	453	90.0	32.9	166.3	237.9	25.6
	451	91.9	24.2	182.3	250.0	50.0
Average		91.0	28.6	174.3	244.0	37.8

[a] Values above 100 indicate larger amounts excreted in the given form than were ingested in that form.

The variations for the forms of phosphorus in the feces in percentage of the amounts of the same forms ingested are marked, both within the lots and between the lots. The cause of these variations is not apparent from the data available. It is, however, evident that the forms of phosphorus of the feeds underwent profound changes during the processes of digestion and metabolism. A large proportion of the acid-insoluble phosphorus of the feeds was converted into acid-soluble phosphorus and a large part of the soluble organic phosphorus was also changed into acid-soluble inorganic phosphorus.

PHOSPHORUS BALANCE

The daily phosphorus balances of the lambs for the continuous 12-day metabolism test are given in Table XVII.

Table XVII.—*Daily phosphorus balances (in grams) of lambs in metabolism test*

Ration.	Lamb No.	Intake.	Output.			Balance.
			Feces.	Urine.	Total.	
Low-protein	468	2.94	2.56	0.016	2.576	0.364
	463	3.34	3.24	.015	3.255	.085
Average		3.14	2.90	.016	2.916	.224
Medium-protein	462	4.48	3.66	.012	3.672	.808
	458	5.11	4.52	.018	4.538	.572
Average		4.80	4.09	.015	4.105	.695
High-protein	453	5.68	5.11	.018	5.128	.552
	451	5.79	5.32	.014	5.334	.456
Average		5.74	5.22	.016	5.236	.504

All of the lambs showed positive phosphorus balances. Even the low-protein lot, which, on an average, ingested 3.14 gm. of phosphorus per day, showed a balance of 0.224 gm. per day. These low-protein lambs were fed the same feeds in the same quantities per 100 pounds of live weight from weaning time, June 25, to January 28, a period of 217 days, as they were fed during this metabolism test. During the main feeding experiment they made an average daily gain of 0.28 pound per head per day. From these satisfactory gains for a period of 7 months and the positive phosphorus balance shown during the metabolism period of 12 days, it is probable that the phosphorus requirement for the normal growth and fattening of lambs is not more than 3 gm. per day per 100 pounds of live weight.

From the available data it is not apparent that there was any correlation between the quantities of phosphorus stored and the quantities of protein and phosphorus ingested.

SUMMARY

(1) There are marked differences in the percentages of the different forms of phosphorus occurring in alfalfa hay, corn, and linseed meal, and in the ratio of phosphorus to protein in these feeds. A large part of the phosphorus of alfalfa hay consists of the acid-soluble inorganic form; the phosphorus of corn is equally divided between acid-insoluble and acid-soluble, the soluble being largely organic; and the phosphorus of linseed meal is largely in the acid-insoluble form, the soluble being about equally divided between inorganic and organic phosphorus.

(2) Upon a ration of alfalfa hay, corn, and linseed meal lambs excrete in the urine only two-tenths to five-tenths of 1 per cent of the total phosphorus ingested.

(3) The forms of phosphorus excreted in the feces of lambs show that the forms of phosphorus in the feeds consumed undergo marked qualitative and quantitative changes during the processes of digestion and metabolism. A large proportion of the acid-insoluble phosphorus of the feeds is converted into acid-soluble phosphorus, and a large part of the soluble organic phosphorus is also changed into acid-soluble inorganic phosphorus. Therefore, there is relatively only a small percentage of acid-insoluble phosphorus and a relatively large percentage of inorganic acid-soluble phosphorus in the feces.

(4) The results of this metabolism experiment, together with those of the main feeding experiment of 217 days' duration, indicate that the phosphorus requirement for the normal growth and fattening of lambs does not exceed 3 gm. per day per 100 pounds of live weight.

(5) There is no evidence of correlation between the amounts of phosphorus retained in the body, on the one hand, and the amounts of phosphorus ingested, the amounts of protein ingested, or the body weights of lambs, on the other hand.

(6) Variations in the quantity of digestible protein consumed from 1.56 to 3.19 pounds per 1,000 pounds of live weight per day by lambs do not influence significantly the forms of phosphorus in the feces, the total phosphorus in the urine, or the total phosphorus stored in the animal body, expressed in percentage of the total phosphorus ingested.

A BACTERIAL DISEASE OF LETTUCE

[A PRELIMINARY REPORT]

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In January, 1915, some diseased lettuce plants (*Lactuca sativa*) were sent to the United States Department of Agriculture from Nairn, La. The letter accompanying them stated that the disease was ruining the lettuce crop in that section, that about 200 acres of lettuce plants were badly infected, and that the fields looked as though a fire had swept through them.

At first the growers thought the disease was due to the excessive use of cottonseed meal, but it was reported in fields where no cottonseed meal was used. It occurred on high land, but was most prevalent on flat land. There had been excessive rainfall for three months in the affected region; however, there were fields within 10 feet of the infected area that showed no visible trace of infection.

The plants received by the Department were full-grown heads with some of the outer leaves entirely shriveled and dried and some of them in a soft-rotted condition. The centers of the heads were sound, but between the center and these dead outer leaves were others affected in varying degrees. In some places there were numerous separated spots with a water-soaked appearance. In other places the spots had fused. Portions of many leaves were in a bad condition, while other parts of the same leaves were sound.

Razor sections of areas showing the earliest evidence of the disease were examined under the microscope, and numerous bacteria were found in the cells and between them. Fungus threads were not detected. In the advanced stages of the disease the palisade cells and the loose parenchyma cells had collapsed. Some of the younger diseased areas were used for isolating the organism presumed to cause the trouble, the isolation being made by means of agar-poured plates. The organism so obtained was proved to be infectious.

Colonies appeared three days after pouring the plates. Those colonies which produced the disease when they were inoculated into healthy lettuce plants were later studied carefully on agar plates. When very young they are round with entire margins smooth, translucent, cream-white in reflected light, bluish in transmitted light, with fish-scale-like markings which are not always present and which do not seem to be on the surface. These markings disappear as the colonies get older. When 3 days old,

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many colonies have a denser margin which is lighter colored than the center. When older, the center is not always uniform in color. It may have yellowish bands or mottlings and patches of the lighter margin color in it. There is not always a definite light margin, and some colonies seem quite uniform throughout. The colonies range from 3 to 5 mm. in diameter. On agar stroke this mottling is present when the culture is young, but disappears in both stroke and plate colony as they get older. Inoculations have been made with the mottled colonies and those uniformly colored—that is, either cream-colored or bluish throughout. All types are infectious.

Using subcultures from single colonies, the disease was reproduced with this organism by needle-prick inoculations four different times (12 plants) and twice by spraying water suspensions of it on middle-aged plants growing in the greenhouses (7 plants). Checks held under the same condition of heat and moisture remained healthy. Reisolation inoculations by means of needle pricks were also made, and these, too, were successful.

The organism is a bacterium,[1] motile by means of from one to three polar flagella; it is non-gas-forming in peptone water with the sugars and alcohols tried (dextrose, lactose, saccharose, maltose, mannit, and glycerin). It did not cloud the closed end in any of the fermentation tubes, but it clouds beef bouillon +15 in less than 24 hours at 23° C. when transfers are made from beef bouillon. In 10 days the bouillon has become a lime-green color.[2] The organism clears sterile milk in 15 days without coagulation, the cleared fluid becoming a pale turtle-green color. It blues litmus milk and will grow in peptone-beef bouillon at temperatures ranging from 1.5° to 34.5° C., though it will not grow in bouillon at 36° C. The thermal death point lies between 48° and 49° C. It grows well in Uschinsky's and Fermi's solutions, changing them to pale Veronese green and water green in 3 to 5 days, but grows very faintly in Cohn's solution. The organism liquefies gelatin slowly at 18.5° C., one-half of the gelatin in test-tube cultures being liquefied in 10 days. On potato cylinders it produces a fleeting dark blue-green color. This striking color reaction develops promptly and disappears on the sixth day or earlier. It grows in bouillon over chloroform, tolerates malic, tartaric, and citric acid (0.1 to 0.2 per cent) added to neutral beef bouillon, but will not grow in neutral beef bouillon containing 0.3 per cent of these acids. It grows readily in neutral and in beef bouillon +5, moderately in −10 and −18, faintly in −20, but will not grow in −22 beef bouillon.

The organism withstands a limited amount of drying. A drop of a 1-day-old bouillon culture smeared over sterile cover glasses and kept in

[1] This use of the genus Bacterium is in accordance with the system of classification proposed by Erwin F. Smith *in his* Bacteria in Relation to Plant Diseases. v. 1, p. 171. Washington, D. C., 1905. (Carnegie Inst. Wash. Pub. 27.)

[2] Ridgway, Robert. Color Standards and Color Nomenclature. 43 p., 53 col. pl. Washington, D. C., 1912.

the dark at room temperature (20° to 23° C.) will produce growth up to the eleventh day of drying when such covers are placed in tubes of beef bouillon.

It is not especially sensitive to sunlight. Petri dishes, one half covered with black paper and exposed bottom up to the noon-day sun in April on a sack of ice, developed 15 to 30 colonies on the uncovered parts exposed for 30 minutes, but none at 40 minutes. The covered part of the 30-minute plates developed from 130 to 150 colonies; that of the 40-minute plates developed from 30 to 55 colonies.

The organism likewise grows in neutral beef bouillon containing 3 and 4.5 per cent of sodium chlorid, but does not grow in the same medium with 5 per cent of common salt. It produces indol, but less abundantly than *Bacillus coli*, and does not reduce nitrates.

Stained from young agar cultures, the organism is a short rod with rounded ends. It is less than 1 to 1.25μ in diameter and 1.25 to 3μ long. It occurs singly, in pairs, and also in chains. Spores have not been observed. The organism stains readily with carbol fuchsin, gentian violet, methyl violet, and methylene blue. It is Gram-positive, and is not acid-fast. The flagella were stained by Loeffler's flagella stain.

A bacterial disease of lettuce has been reported from the Vermont, the Massachusetts, the Florida, and the North Carolina experiment stations. Pietro Voglino (1904)[1] in Italy has reported a bacterial disease of lettuce and named his organism "*Bacillus lactucae*." As the description of the organism reported in his paper does not agree with our own (pink, nonliquefying, spore-bearing, etc.), it is clear that the Louisiana organism is not the same as the Italian, but is possibly the same as some one of the unnamed forms previously isolated in this country and not carefully described. The name "*Bacterium viridilividum*, n. sp.," is suggested for the one under consideration, owing to its peculiar appearance on steamed potato.

For purposes of orientation, a short account of the literature on bacterial diseases of lettuce follows:

L. R. Jones (1893)[1] has given an account of a bacterial stem-rot of lettuce. A large bacillus was found in the diseased stems, but was not isolated. He reproduced the disease (1) by planting healthy plants in soil inoculated with fragments of lettuce plants affected by "stem rot," (2) by crushing a diseased lettuce head in a little water and pouring this water about the roots of healthy plants.

G. E. Stone (1907) mentions a bacterial disease of lettuce leaves which had been investigated by Mr. Percival C. Brooks six years earlier. It is stated that Mr. Brooks isolated an organism and produced positive results from inoculation experiments. As the disease was believed to

[1] Bibliographic citations in parentheses refer to "Literature cited," p. 478.

be of little consequence, no extensive study was made. There is no description of his organism.

F. L. Stevens (1908), in a short report on a bacterial disease of lettuce, states that the bacteria isolated were rather long rod forms. His attempts at inoculation were unsuccessful.

H. S. Fawcett (1908) also reports a bacterial disease of lettuce. He likewise isolated an organism and reproduced the disease. His colonies on standard peptonized agar had indefinite margins and pearl-white foci. The organism stained readily in carbol fuchsin and aqueous gentian violet, but with difficulty in methylene blue.

O. F. Burger (1912) describes a bacterial disease of lettuce which he says is caused by a species of Pseudomonas. The disease begins at the center of the head, which blackens and then becomes soft. In the seed bed the disease appears as small black spots on the leaves. This does not seem to be the type of disease that occurred in Louisiana this year. Burger states that cultures of the bacteria were made and healthy lettuce plants were inoculated. In 10 days the inoculated plants were black and pulpy, while the checks were still healthy.

Bacterium viridilividum does not agree with the descriptions of any of the organisms mentioned by these writers. Voglino's (1904) organism evidently does not liquefy gelatin, and the colonies in lettuce gelatin change from an ivory-white color to a rosy tint. *B. viridilividum* liquefies gelatin, and is never ivory white or of a rosy tint. Fawcett's (1908) organism produces colonies with indefinite margins and pearl-white foci and stains with difficulty in methylene blue. *B. viridilividum* has definite margins, no pearl-white foci, and stains readily in methylene blue. Stevens's (1908) organism is a long rod form; *B. viridilividum* is a short rod. Stevens's inoculations were not successful. Jones (1893), Brooks (Stone, 1907), and Burger (1912) did not describe their organisms.

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